SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 70

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 2655)

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CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 70, NUMBER 1

A LOWER CAMBRIAN EDRIOASTERID

Stromatocystites walcotti

(WITH ONE PLATE)

BY
CHARLES SCHUCHERT

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A LOWER CAMBRIAN EDRIOASTERID
Stromatocystites walcotti

By Charles Schuchert

(With 1 Plate)

In 1910, while the writer was studying the stratigraphy of western Newfoundland, he was much surprised to find in the Lower Cambrian a number of cystids that seemed to be related to the edrioasterids. These and other Lower Cambrian fossils were collected for the United States National Museum, and the study of the edrioasterids was kindly turned over to the writer by the Secretary of the Smithsonian Institution. In admiration of the long-continued and excellent work which the latter has done on the Cambrian, in the midst of seemingly endless administrative duties, the new species herein described is given the name *Stromatocystites walcotti*.

It was thought at first that these fossils represent a new genus, but after seeing two specimens of *Stromatocystites pentangularis* from the Middle Cambrian of Bohemia, which are in the Peabody Museum collection in Yale University, it became clear that the Newfoundland form is a species of *Stromatocystites*. Accordingly, we will begin with a definition of that genus, in the main as given by Pompeckj.[1]

Stromatocystites (*redefined*)

Text fig. 1 E

This is a flat and depressed cystid, and it is this spread-out condition that has suggested the name. Theca free, unstalked, subpentagonal in outline, and composed of numerous comparatively large, non-imbricating, and usually five- and six-sided plates. In a theca 35 mm. in diameter there may be 1,000 plates. Upper surface convex, lower one concave. Ossicles of the upper side bearing, along each angulation of their margins, usually 2 to 3 diplopore depressions that extend across the sutures of adjoining plates; on the

[1] J. F. Pompeckj, Jahrb. d. k. k. Geol. Reichs., Vienna, 45, 1895, pp. 505-508, pl. 13, figs. 1-6. Also see F. A. Bather, Treatise on Zoology, Part III, Echinoderma, p. 206, fig. 1.

inner sides they are seen as two tiny apposed hydrospire elevations. Plates of the lower side very finely pitted, but it is not thought that these pits bear pores going through the plates to the body cavity.

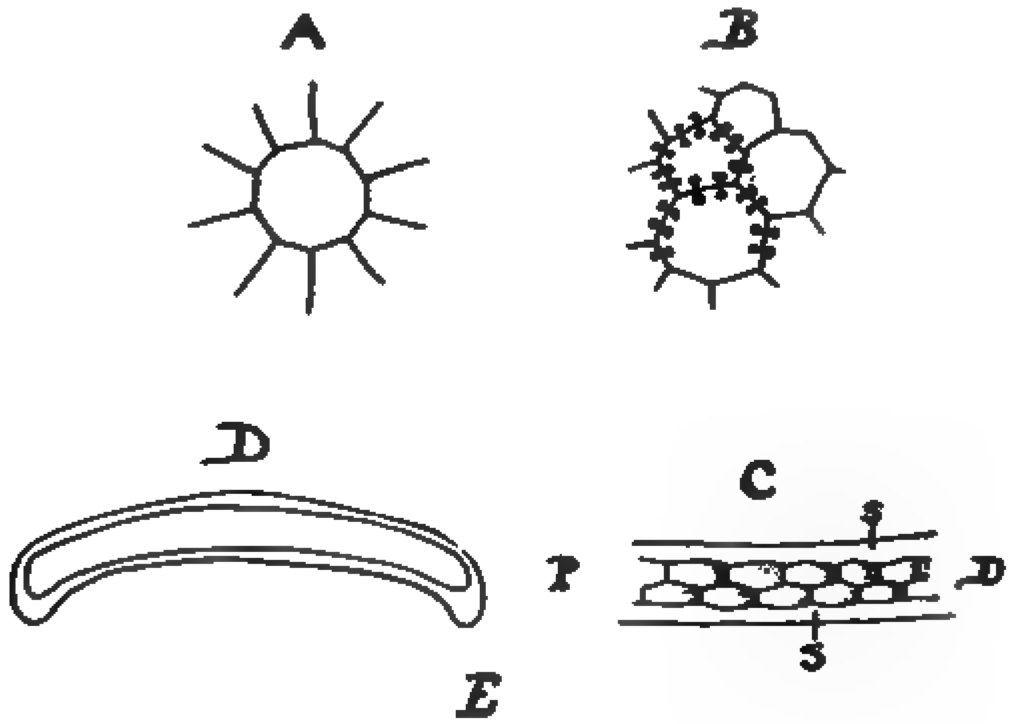

FIG. 1.—A, *Stromatocystites walcotti*, n. sp. The centrodorsal plate, and the first circle of 10 plates in outline, × 5. B, *S. walcotti*, n. sp. Some of the plates of the upper side, showing the diplopore spiracles, as seen from their inner surface, × 5. C, *S. walcotti*, n. sp. Part of an ambulacrum showing the flooring plates, × 5. *D*, distal, *P*, proximal end; *s*, ridges of the side plates. D, *S. walcotti*, n. sp. The animal in section, × 2. E, *S. pentangularis* Pompeckj. A restoration of the upper surface by F. A. Bather, somewhat enlarged. *As*, anus, *O*, peristomial plates, *c. p.*, covering plates, *s. p.*, side plates, *ia*, interambulacrals.

Ambulacra restricted to the upper side, straight and narrow, bounded on either side by a column of about 11 to 13 narrow elongate plates; ambulacral groove deep and seemingly floored by two columns of elongate, narrow, and alternating flooring pieces; the two columns

of alternating covering plates highly arched over the ambulacrum, about as wide as long, and from 11 to 13 in number. Pompeckj sees podial perforations, but in the writer's specimens none such appear to be present. Mouth on upper side, covered by a number of imperforate plates, of which 4 are large and peripheral, with several smaller ones between them. In addition, there are others of the ambulacra. Anus in the bivium of the upper side, and covered by a pyramid of about 9 small ossicles.

Genotype.—S. pentangularis Pompeckj, Middle Cambrian of Bohemia.

STROMATOCYSTITES WALCOTTI, new species

Plate 1, figs. 1-4; text fig. 1 A-D

This new diplopore-like edrioasterid is the oldest one known, being from the upper portion of the Lower Cambrian. When alive, these animals sat somewhat anchored upon the sandy mud, but they were in no way cemented to sea bottom nor to foreign objects. The loose anchoring was by means of the sharply bent and closely folded, projecting marginal rim, which was pressed down into the mud, assisted by the concavity of the under side of the theca (see fig. 1 D). Impressions of this rim are of common occurrence on the weathered rock surfaces, though the calcareous plates are usually dissolved away by the percolating waters (pl. 1, figs. 2 and 4). The plates of the rim were somewhat thicker and far more irregular in shape and size than those of either the lower or upper discs. In fact, there is a tendency to form a ring of large plates, with many smaller irregular ones about them. None of the plates are imbricating. The under side of the animal is slightly concave, while the upper one is depressed convex. The body cavity is very shallow, probably less than 3 mm. in depth.

Stromatocystites walcotti is subpentagonal in outline, with the greater diameters varying between 18 and 22 mm. The ambulacra are restricted to the upper surface, are comparatively narrow, but with distinct and sharply elevated, nearly parallel sides which are deep and straight and terminate in the angles of the pentagon. The ambulacra are roofed over by small covering plates whose detail is not preserved. The ambulacral grooves are distinctly floored by two columns of elongate alternating plates, numbering between 11 and 14 in each row. None of these plates is perforated (see pl. 1, figs. 1-3 and text fig. 1 C). The side plates are not well preserved, but they

appear to be narrow elongate pieces and about as many as there are ambulacrals, with which they alternate. The mouth area is not preserved.

The interambulacral areas of the upper disc are composed of slightly convex, usually six-sided plates, which are rather large in comparison with the size of the animal. Of these there appear to be between 120 and 130. From one to two, and at times three, diplopores cross the sutures of each plate angulation, and these are far more distinctly seen on the inside of the plates because of the pairs of sharp but tiny spiracle elevations (text fig. 1 B, and pl. 1, fig. 3). The anal pyramid is unknown.

The plates of the under side of the animal are also non-imbricating and apparently in the main six-sided; they appear to be somewhat smaller than those of the upper side. Their number seems to be between 140 and 160. In the center of the under surface there is a comparatively large centrodorsal plate, about 2 mm. in diameter, around which there is a ring of 10 elongated plates (pl. 1, figs. 2 and 4, text fig. 1 A). All of the plates of the under surface are finely pitted, and these are arranged obscurely in lines across the sutures of adjoining plates. They are too delicate to be remnants of vanishing diplopores, and are probably nothing more than the similar pittings seen in many cystids (pl. 1, fig. 3).

As the specimens come in two sizes and on different horizons of the Lower Cambrian, the name *Stromatocystites walcotti* is applied to the larger form above described, of which 6 individuals are known. The smaller ones are far more common, 25 being at hand, and they vary in diameter from 9 to 15 mm. Because of their smaller size they are here distinguished as variety *minor*. All that is preserved of these smaller specimens is the impressions of the marginal plates (pl. 1, fig. 4).

Locality and horizon.—In the Olenellus beds of the Lower Cambrian (Taconian) of East Arm of Bonne Bay, western Newfoundland. The type material is in the collection of the U. S. National Museum, catalogue numbers 66443, 66444.

Remarks.—Bather states that *Stromatocystites* "was probably sessile on its under surface but perhaps not fixed permanently." The word sessile may be interpreted as meaning sitting upon, or attached to something, and it is in the former sense that we must here accept the significance of sessility. In both the European and American forms, the under thecal surfaces do not show the slightest scar or modification such as would follow if the animals were firmly attached

or cemented to the ground. Of course they were not errant animals, but were, rather, stationary in habit and loosely anchored to the muddy and sandy sea bottom by the concave under side and the downward projecting margin of the theca. This naturally was a rather precarious footing in a shallow sea, and undoubtedly the storm waves often pulled them away from their moorings.

In regard to disposition among the Echinoderma, *Stromatocystites* is at first sight somewhat perplexing. On the one hand, it is clearly related to the diplopore-cystids in its thecal structure, and the five ambulacra appear to be nothing more than modified recumbent brachioles attached to the thecal plates. Yet it is not one of these cystids, because *Stromatocystites* was a free animal devoid of a stalk, though retaining at times centrodorsal plates. On the other hand, the genus is clearly on the line of evolution to the sessile edrioasterids, but is an unattached although not an errant form. That *Stromatocystites* is already plainly on the line toward the edrioasterids is indicated by the structure of the ambulacra. This is seen in the modification from the diplopore-cystids, where the free brachioles are composed of two columns of alternating thick ossicles having their ambulacral furrows covered over by two rows of roofing plates. These four columns of ossicles are, in the genus under consideration, the equivalents of the roofing and flooring plates of the ambulacra, but there are in addition, the two columns of side plates, a new development not present in the brachioles of diplopore-cystids. In these features we therefore seem to see how a diplopore-cystid changed into the loosely anchored *Stromatocystites,* at the same time trending in development toward the true edrioasterids.

In 1905, Jean Miquel described a new form as *Stromatocystites cannati,*[1] from a single specimen. It comes from the Middle Cambrian of the Montagne Noire of France, and is peculiar in having a much modified lower rim. Miquel says that the margin has very large rectangular plates, and that each of the sides of the pentagonal disc has from 3 to 5 of them. As the specimen is somewhat crushed, and as an uncrushed side of the pentagon has 5 large marginal plates, this may be taken as the actual number, so that there were about 25 much modified ossicles in the anchoring rim of the lower side. The lower thecal side is not described and is probably unknown. "The ambulacra," Miquel says, "attain the extremity of the circumference, and accentuate the angles of the pentagon; they

[1] Bull. Soc. géol. France, 4th ser., vol. 5, 1905, p. 482, pl. 15, fig. 5.

are formed of two ranges of plates, small, regularly arranged, with a quite large size, which decreases from the mouth of the animal to their extremity. The species has in general form much analogy with *S. pentangularis* Pompeckj." It differs clearly from this form "by the size of the ambulacra and by the arrangement of the thecal margin."

Even this meager description shows that it is not a *Stromatocystites,* but that it is plainly an edrioasterid. The marginal plates are already those of edrioasterids.

Relation to asterids.—The edrioasterids are particularly interesting fossils because the oldest forms seem to indicate the stock out of which they arose, and at the same time appear to be near the forms that gave rise to the asterids. Bather was the first to point out this phylogeny and he has written at length about it. We will therefore follow his argument.

The oldest known asterids are of Middle Ordovician time, but here there are already large forms in considerable variety, and the structural differentiation among them is great.[1] This of course must mean a much older origin for the asterids. On the other hand, edrioasterids go back to the late Lower Cambrian, and if the asterids arose in the edrioasterids, we must look for small, subpentagonal, diplopore-cystid-like, ancestral asterids certainly as early as the Middle Cambrian and probably as far back as the Lower Cambrian.

The origin of the starfish line may have been brought about, according to Bather,[2] as follows: "If we imagine an edrioasteroid with loose attachment, liable to be overturned by currents . . . . then all we have to suppose is that some of the overturned individuals were able to survive the accident. This they would be able to do if they had fairly well developed podia, such as are indicated by the anatomical evidence. . . . . Indeed, it is hard to see how locomotion could have been avoided."

The home of *Stromatocystites,* in both Europe and America, was a shallow sea near a shore, where there was rapid accumulation of sand and mud. Many of the strata of the Lower Cambrian of Newfoundland are rippled, and the organic and facial evidence is of shallow seas, certainly less than 200 feet in depth, with the probability of even less than 100 feet. In such a sea, the greater storm waves could easily pick up the bottom and roll it about, carrying along with

[1] See Schuchert, Revision of Paleozoic Stelleroidea, Bull. 88, U. S. Nat. Mus., 1915, pp. 27-31.

[2] Bather, Geol. Mag., dec. 6, vol. 2, 1915, p. 403.

it the *Stromatocystites*. The animals had to battle constantly against this danger, and through the aid of their breathing podia probably did dig themselves out when accidentally covered by the muds. Such treatment often repeated, as it must have been, might well have been the stimulus that brought about forms that learned how to creep around on their nutrient ambulacral surface through the aid of their breathing podia. In this way breathing podia were changed into locomotor podia like those of asterids. At the same time, the passive funnel-like mouth of *Stromatocystites* evolved into the active predatory organ of asterids.

In the permanently overturned condition, with the mouth beneath the disc, such as occurs in a form similar to *Stromatocystites*, Bather states that the hydropore and anus would have to migrate along the posterior interradius toward the aboral pole, and in consequence the stone-canal would become elongated. The ambulacra and the covering plates became the ambulacra and adambulacra of asterids. On the other hand, the side plates of edrioasterids appear to be new structures not present in diplopore-cystids, and they may well be the equivalents of the inframarginalia of primitive Paleozoic asterids. The mouth frame in edrioasterids is composed of 15 plates (the five interradials are here fused plates, so that originally there were 10 of them), while in starfishes the more primitive form of 20 pieces is often retained. All were originally ambulacral and interambulacral (=adambulacral) structures.

PLATE 1

FIG. 1.—*Stromatocystites walcotti*, n. sp. A slightly slickensided specimen from the upper side, × 2.

FIG. 2.—*S. walcotti*, n. sp. A natural mold, × 2. Showing the centrodorsal plate and the ossicles of the rim. On the right is preserved some of the filling of the body cavity, which retains the imprint of the inner sides of the plates of the upper surface.

FIG. 3.—Same specimen as fig. 2, × 5. To show the pitting of the plates of the lower side, and the spiracles of the plates of the upper side.

FIG. 4.—Four impressions of the lower side of *S. walcotti minor*, n. var. Natural size.

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EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1918

(Publication 2535)

CITY OF WASHINGTON
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1919

[...]RATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1918

INTRODUCTION

[...]ore important of the explorations and researches in the [...]ducted or participated in by the Smithsonian Institution [...]he year 1918, are herein briefly described. While in many [...] work was considerably restricted by the world war, never-[...]results of importance to science were accomplished and [...]able material was added to the natural history and ethno-[...]collections in the United States National Museum. Nearly [...]ranch of science is represented among these researches, [...]g anthropology, ethnology, geology, botany, zoology, and [...]ysics.

[...] work of the Smithsonian Astrophysical Observatory in [...]ring the amount of radiation from the sun is of increasing [...]ance, as it is expected to make these measurements the basis [...]ew method of forecasting temperatures on the earth. The [...]ogical studies among the tribes of American Indians are of [...]l interest as certain of these tribes are fast disappearing, in [...] cases only a very few persons surviving who remember the [...]age, customs, and traditions of a once powerful people. This [...]logical material is being recorded from the Indians themselves [...]embers of the Bureau of American Ethnology and so preserved [...]uture generations.

[...]e brief accounts contained herein are largely written and the [...]ographs taken by the investigators themselves.

[...]EOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

[...]he geological explorations carried on in the Canadian Rocky [...]untains by Dr. Charles D. Walcott, Secretary of the Smithsonian [...]itution, which have been mentioned in the Exploration Pamphlet [...]the Institution for the years 1916 and 1917, were continued during [...] field season of 1918 for the purpose of ascertaining the geological [...]ucture of the Upper Bow Valley north of Lake Louise, Alberta, [...]d later at the head waters of the Cascade River at Sawback Lake, [...]d also to locate any possible occurrence of unusual beds of fossils [...] these places.

Passing up the Bow River from Banff there is a beautiful view from Vermilion Lakes of the western slope of Rundle Mountain near Banff (fig. 2). To the north Mount Louis in the Sawback Range thrusts its pinnacles of upturned limestones far above timber-line (fig. 3). The pinnacles when seen from the north present a bold, strong sky-line (fig. 4).

Leaving the Canadian Pacific Railway at Lake Louise Station, the Bow Valley extends to the northwest parallel to the Continental Divide which forms its southwestern side. Bow Lake at the head

FIG. 2.—Southwest slope of Rundle Mountain, looking across Vermilion Lakes, 2 miles (3.2 km.) west of Banff. The mountain is composed of sloping limestones that form bold eastward facing cliffs. Photograph by Walcott, 1918.

of the valley is a beautiful sheet of water hemmed in by bald mountain slopes and cliffs on the west and north and by the mass of Mount Hector (11,125 feet) on the east. From the west numerous glaciers drain into the lake. The first one encountered is Crowfoot (fig. 5), which flows from the great Wauputek snow-field along the Continental Divide. Some of the smaller glaciers bring down an immense amount of broken and ground up rock which forms long slopes extending nearly to the edge of the lake (figs. 6 and 7).

Fig. 3.—To the northwest of Banff, Mount Louis in the Sawback Range thrusts its pinnacles of upturned limestones far above timber line. Photograph by Walcott, 1918.

Fig. 4.—Pinnacles of Mount Louis seen from the north present a bold, strong sky-line. Photograph by Walcott, 1918.

Bow Peak

Crowfoot Mt.

Crowfoot Glacier

Mt Breese

FIG. 5.—View from the west slope of Dolomite Peak, looking westward and southwestward across Bow Lake, which is 19 miles (30.4 km.) north-northwest of Lake Louise. In the center Crowfoot Glacier. To the left center Crowfoot Mountain, and in the distant left Bow Peak. To the right of the Glacier Mount Breese with a small glacier on its eastern slope. Photograph by Walcott, 1918.

Fig. 6.—Small glacier in an amphitheater on the eastern slope of Mount Breese (see fig. 5) with a great talus slope that extends from the foot of the glacier nearly down to the waters of the lake. Photograph by Walcott, 1918.

Mt. Molar

Bow Peak

Crowfoot Mt and Glacier

Mt. Breese

FIG. 7.—Panoramic view from the northeast ridge of Mount Thomson, looking south across Bow Lake. On the right above the lake Mount Breese, and on the left of it Crowfoot Mountain with the snow field of Crowfoot Glacier. At the foot of the Lake, Bow Peak and in the distance Mount Hector. To the left Mount Molar (see fig. 8). Photograph by Walcott, 1918.

Figure 7 pictures Bow Lake as seen from the eastern slope of Mount Thomson. This view over the lake from the north shows the ridges on the right formed of Middle Cambrian limestones, while far away in the distance the snow-clad summit of Mount Hector is buried in the clouds. In figure 8 is shown a nearer view of Mount Molar, a beautiful example of horizontally bedded limestones, illustrating the manner in which the hard, evenly bedded limestones erode into domes and broad cylindrical masses.

FIG. 8.—Mount Molar (9,914'), a high mountain ridge to the east-southeast of Bow Lake. Photograph by Walcott, 1918.

There was fine trout-fishing at the lower end of Bow Lake, and we met with both deer and grizzly bear in the somewhat open valley at the head of the lake (fig. 9).

The snow-fields from which Bow Glacier flows are on the Continental Divide between the Bow Valley and the Upper Yoho Valley. The glacier flows down a gentle slope for a mile or more, and then breaks over a high cliff, as shown in figure 10. There are beautiful camping grounds on the shores of both Hector and Bow lakes, especially the latter. From one of these camps (fig. 11), geological sections were measured of the Cambrian rocks on the eastern slope of Mount Thomson.

Mt Breese St. Nicholas Mt. Bow Glacier Portal Peak Mt. Thomson

FIG. 9.—Panoramic view from the northeast end of Bow Lake. In the center Bow Glacier, and to the right Portal Peak and Mount Thomson. To the left of the glacier St. Nicholas Mountain, in the center Mount Breese. This view should be studied in connection with figure 7. Photograph by Walcott, 1918.

St. Nicholas Mt.

FIG. 10.—View of Bow Glacier from our camp at the head of Bow Lake. This is a beautiful illustration of a glacier cascading or falling over a high cliff. Photograph by Walcott, 1918.

Fig. 15.—Peyto Glacier and Lake from the cliffs of the east shore of Peyto Lake on the northwest side of Bow Pass, 24 miles (30 km.) in an airline north-northwest of Lake Louise Station.

On the left above snow line the Continental Divide, Peyto snowfield or nevé, glacier, ice foot, terminal moraine, and flood plain. Photograph by Walcott, 1918.

Mount Wilson

FIG. 17.—Panoramic view looking north across head of Saskatchewan River. The valley of the North Fork is shown on the left of Mount Wilson (11,000′). The Saskatchewan is here a large and rapid stream just below the union of the north and west forks. It is wonderfully picturesque, and on the mountains to the left we saw large numbers of mountain goats, some of which we were so fortunate as to obtain a photograph of. Photograph by Walcott, 1918.

FIG. 18.—Group of mountain goats endeavoring to escape over a sharp ridge immediately in front of where Mrs. Walcott was watching for them. The one attempting to go around the point on the left is on the edge of a cliff about 50 feet above the river. The goat at the top is apparently attempting to prevent itself going over backward by throwing its head forward. Photograph by Walcott, August 5, 1918.

lakes by the rock and dirt brought down by the glacier from the higher mountain slopes. A nearer view of Peyto Glacier is given in figure 15, and figure 16 shows Pyramid Peak, one of the peaks encountered in the Mistaya River Canyon.

The broad canyon valleys that unite at the head waters of the Saskatchewan River (fig. 17) are all carved by erosion out of the same type of Cambrian rocks as those exposed in the vicinity of Bow Lake, and also in the Bow Valley south of Lake Louise Station.

FIG. 19.—Skinning out mountain sheep shot above head of Sawback Lake on September 21. Photograph by Walcott, 1918.

At the close of the season a fine pair of mountain sheep, a black bear, one mule deer, a mountain goat, and a wolverine were collected, the skins and skulls being shipped to the National Museum. At a salt-lick on the west branch of the Saskatchewan River many goats were seen. Some of them in an attempt to escape observation were forced to pass over a sharp ridge directly in front of where Mrs. Walcott was sitting, with the result that she obtained an unusual photograph of five of them (fig. 18) as they were clambering over the apex of the ridge.

Fig. 20.—Panoramic view looking across Sawback Lake eastward toward the Vermilion Range. The lake is about 16 miles (25.6 km.) in a straight line northwest of Banff, Alberta, Canada, and a favorite fishing grounds for the anglers of Banff. Photograph by Walcott, 1918.

GEOLOGICAL AND PALEONTOLOGICAL FIELD-WORK

The field-work of the Division of Geology during 1918 was limited largely to the collection of material for the school and duplicate series and for the use of the Naval Experiment Station in a newly devised apparatus recently brought into use. In connection with the latter work, the head curator made two trips, one through the principal museums of the eastern United States, and subsequently, one extending from northern Georgia through western North Carolina. In addition to the material obtained for the Navy Department, a statement of which is included in a report to the National Research

FIG. 21.—Arriving at home on the trail at eventide, and looking over the horses before turning them out for the night. This camp, below Wolverine Pass, is in one of the most interesting localities in the mountains south of Lake Louise. Photograph by Walcott, 1918.

Council, there was secured a considerable amount of bauxite, staurolite crystals, and numerous specimens of other desired materials, such as columbite, pitchblende, albite, black mica, and quartz.

Dr. Martin, assistant curator of geology, U. S. National Museum, was detailed to spend two weeks in Virginia and Maryland making collections of material to illustrate the weathering and decay of the commoner types of rocks. A sufficient quantity of each phase of the process was taken to make up 100 sets intended for distribution

primarily to such agricultural and other colleges as give instruction in rock weathering and soil formation. A series of from two to four specimens was obtained from each of the seven varieties of rocks showing the fresh and intermediate steps in the present stage of its decomposition. The types selected include granite-gneiss, diabase, gabbro, soapstone, sandstone, and limestone. The railroad cuts in the vicinity of North Garden and Chatham in Virginia, and Mount Hope and Washington Junction in Maryland, afforded, respectively, the granite-gneiss, diabase, gabbro, and sandstone, and the quarries at Alberene, Virginia, and Frederick, Maryland, yielded the soapstone and limestone. In every case the oxidation had proceeded sufficiently to result in the formation of reddish- or yellowish-brown soil, but in the case of the North Garden granite-gneiss, perfectly fresh rock could not be obtained. To supply this deficiency, a series of specimens from the granite-gneiss of the District of Columbia was included, although its weathering had not passed the stage of mechanical disintegration. Despite the fact that such materials do not readily lend themselves to exhibition purposes, several choice residual nodules of gabbro and diabase (so-called nigger heads) one to two feet in diameter were collected for Museum display.

In order to fill certain gaps in the ore and rock collections, Dr. Martin was also detailed to visit localities in Pennsylvania, New Jersey, and New York, and secure a quantity of material from each. Brandywine Summit, Pennsylvania, yielded some excellent cleavage fragments of orthoclase; Peekskill, New York, a select grade of emery rock; North River, New York, hand size pieces of abrasive garnet. From the dikes at Franklin Furnace and Beemersville, New Jersey, was secured a supply of uncommon intrusive rocks, camptonite and nepheline-syenite respectively. Both of these formations, as well as the peridotite, associated with the emery and the syenitic country rock of the garnet, were found to have suffered considerably from the action of the weather since glacial times, and appropriate specimens showing this process were collected incidentally for the study series.

During the field season of 1918, Drs. R. S. Bassler and C. E. Resser of the Division of Paleontology continued the search begun in recent years for large exhibition specimens to illustrate the various phases of structural geology and stratigraphic paleontology. Dr. Bassler

rocks in one of the open pits with the ore bed (O) at the bottom, above this the Early Paleozoic limestone (P), and capping the limestone, the red beds of Mesozoic age (M).

FIELD-WORK OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY

As usual, for some years past, the Astrophysical Observatory maintained its observing station on Mount Wilson and the work was in the hands of Mr. L. B. Aldrich. As heretofore, the principal object was to follow by accurate measurements the variations in the radiation of the sun as that would be found if one were on the moon, for example, outside the earth's atmosphere. The season did not prove particularly favorable for this work on account of unusual cloudiness. Nevertheless, Mr. Aldrich made many solar-constant observations that will be unusually valuable on account of the possibility of comparing them with similar observations made in South America, which will be related below.

It happened that a station of the U. S. Aviation Service was located near Mt. Wilson, at Arcadia, and military balloons not infrequently passed up through the layer of fog which often covers the San Gabriel Valley, lying between Mount Wilson and the sea. It occurred to Mr. Aldrich to take advantage of this condition of affairs to make a measurement of the reflecting power of such a great layer of fog with a view to the applicability of such measurements to a consideration of the temperature of the planets Earth and Venus, both of which are to a large degree covered with clouds. We have at the Astrophysical Observatory an instrument called the pyranometer, devised by Messrs. Abbot and Aldrich for the purpose of measuring the heating effect of radiation received from a whole hemisphere. For example, the heat from the sun and sky combined, or from the sun alone, or from the sky alone, as it falls upon a horizontal surface may be determined by this instrument. Mr. Aldrich's plan, therefore, was to expose the pyranometer upright to the sun and sky combined, and inverted to the radiation coming up from the layer of fog. For this purpose he needed a support for the pyranometer above the fog, and such a support he thought might be furnished by a military balloon.

With the approval of General Kenley the investigation was made on a favorable day in September, when the upper and lower surfaces of the fog lay respectively about 2,800 feet and 1,000 feet above the ground. Two officers and 50 men being detailed to aid

measurements being made at Calama, Chile, under the direction of Mr. A. F. Moore, assisted by Mr. L. H. Abbot. The outfit there is the same that was used by them during the previous year at Hump Mountain, in North Carolina. The present station was chosen as the most cloudless one to be found upon the earth, and they have been able to observe about 75 per cent of the days since the 27th of July,

FIG. 28.—The Coelostat, Pyrheliometers, and Theodolite.

FIG. 29.—Part of the Spectro-Bolometer.

when the measurements began. For long periods of time, as, for example, the period from the middle of November to the middle of December, there was not a single day lost, although this required that the sky should be perfectly cloudless for about three hours, either in the early morning or the late afternoon. Notwithstanding the great number of favorable days for the observations, the records

of meteorological observations there in former years led us to hope for an even larger proportion of favorable sky conditions. However, in many parts of the world the past two years have been exceptional in their weather and it is to be expected that these exceptional conditions affected the weather of the Nitrate Desert of Chile as well. We therefore hope that in future years even better results may be obtained than now.

The purpose of the work is to follow the variations of the sun and to lay a foundation for the application of such measurements to the prediction of terrestrial temperatures. That branch of the investigation has been taken up by Dr. H. H. Clayton of the Meteorological Service of Argentina. Dr. Clayton has studied the correlations

FIG. 30.—Recording Observations.

between the solar-constant results and the temperatures of Argentina and he is quite enthusiastic as to the probability that the forecasting of the weather in Argentina will be materially improved by the aid of solar-radiation measurements. If this proves to be the case, it is greatly to be hoped that means will be found to increase the number of observing stations qualified to measure solar radiation. The station occupied in Chile lies on the Loa River, also on the railroad from Antofagasta to Bolivia, about 150 miles east of Antofagasta. The altitude is 7,500 feet and the conditions about the station are entirely desert conditions, except in so far as modified by irrigation from the Loa River. The station occupied is a disused mining property of the Chile Exploration Company, which very generously allows its use for the purpose of the solar work. Every effort is being made to

eral management was to be placed in the hands of Mr. R. L. Garner, well known by his previous studies of chimpanzees and gorillas in the same region. Mr. Robert Aschemeier, an assistant taxidermist on the Museum force, was detailed to accompany the party. It was decided that the expedition should be known as the "COLLINS-GARNER CONGO EXPEDITION, IN THE INTERESTS OF THE SMITHSONIAN INSTITUTION."

Mr. Aschemeier and Mr. Garner sailed from New York for Bordeaux about the middle of December, 1916, Mr. Collins then expecting to follow a few months later. War conditions, however, greatly delayed the arrival of the first members of the party in Africa and have entirely prevented Mr. Collins, now Major Collins, from joining them.

After many difficulties had been overcome, largely through the extreme courtesy of the Governor General at Brazzaville, the Lieutenant Governor, and the Administrateur des Colonies at Fernan Vaz, Mr. Garner and Mr. Aschemeier finally established permanent headquarters. The following passages from a letter from Mr. Garner to Dr. Hrdlička give an idea of their surroundings:

"FERNAN VAZ, July 7, 1918.

"Our domicile is located on the edge of a vast plain, traversed here and there by belts and spurs of forest. In those plots of bush live great numbers of chimpanzees, and for the first time in my long experience among them I have seen whole families of them out on the open plain. Frequently they cross the plain from one belt of bush to another, in some places a mile or so in width and not a tree or bush in that distance to shelter them from attack. They often come within 200 to 300 yards of my house and sometimes manifest deep interest in trying to find out what this new thing is, set up in their midst. I have seen as many as four or five different groups of them in the same day, and one of these contained 11 members. One very old man has come, on two occasions, within 100 yards of me and scrutinized me very closely, while his wife (as I took his companion to be) appeared to be very uneasy and suspicious. On several occasions I have seen the young ones romping and tumbling about on the grass, chasing and scuffling with each other, exactly as you see human children do. A school of them slept, a few nights ago, within less than 100 yards of my house, in a very small clump of bush, not more than a hectare in extent, on one side of which is Lake Fernan Vaz and all around the rest of it an open plain, with the quarters of

my crewmen not more than 200 yards away on the opposite side from me and a native village in plain view 500 yards away at an angle of about 30° from the crewmen's village. I have never before seen so many chimpanzees as I find here and I have never seen them so indifferent to the presence of human beings. Even while I was building and had as many as 18 or 20 natives moving about the place those reckless apes would often cross the open plain in full view and with apparent composure.

"Mr. Aschemeier has collected well on to 2,000 specimens and nearly all of them he has killed with his own gun. Some of these specimens are exceedingly rare and valuable. When you recall the fact that he came as taxidermist of the expedition and not as *chasseur,* he was not expected to provide the specimens that he was to preserve.

"We have forwarded six consignments of specimens to the Museum and have a seventh well on the way; but we find great difficulty in getting the steamers to take them from Port Gentil (Cap Lopez), because they are all under direction of the French military authorities. Two of our last shipments were still at Port Gentil last month, where one of them has been lying since last January and all steamers declined to take it. Once both shipments were taken aboard the steamer and bill of lading signed when the captain changed his mind and sent the whole lot back on shore, with the accumulated charges of 40 francs for embarkation and debarkation.

"We have sent 12 or 13 specimens of buffalo, several specimens and species of antelope and two or three fine specimens of the "red river hog," besides a large collection of monkeys, representing six or seven species of both sexes and various ages. I think in all we have sent over 1,500 up to this time. Of course this includes birds, etc., not insects, and we have on hand a goodly number.

"Yesterday I bought a fine, fresh skin of a thing the natives call *anima.* It is something very much like the civet cat in its general appearance, but it is not of the ordinary type. I have never examined one, but I think they are more canine than feline and the natives regard them as such. At any rate, it is a fine specimen and I am taking great care to cure it in the best manner possible.

"I will call your attention to a singular fact about the monkeys and especially of the mangabeys of this region. There appears to be prevalent among them some kind of disease resembling cancer, and it is not at all unusual to see one with his nose eaten away or sometimes one side of his face, while otherwise he appears active and

Fig. 33.—Skull of West African Buffalo collected by Robert Aschemeier.

MARINE BIOLOGICAL STUDIES IN CALIFORNIA

Under the auspices of the United States Bureau of Fisheries, Waldo L. Schmitt, of the Division of Marine Invertebrates, U. S. National Museum, spent the months of August, September, and October in California engaged in a study of the life history of the West Coast spiny lobster, *Panulirus interruptus* (Randall).

The greater part of the time, by courtesy of the Scripps Institution for Biological Research, was spent at their laboratories at La Jolla, examining their extensive plankton collections for the larval stages of the "lobster." Considerable material, chiefly of the younger stages, was obtained here, including many specimens of the post-embryonic stage, hatched by Mr. P. S. Barnhart, curator of the institution's museum, in one of their large aquarium tanks. And further, the assistance extended by the director, Dr. Ritter, enabled Mr. Schmitt to conduct a two-day dredging and tow-netting trip both outside and inside of the extensive kelp-beds lying between La Jolla and Point Loma.

An examination was also made of the collections of the University of California at Berkeley, Stanford University at Palo Alto, the University of Southern California at Los Angeles, Pomona College at Claremont, the Venice Marine Biological Station (of the University of Southern California) at Venice, the Laguna Marine Laboratory (of Pomona College) at Laguna Beach, and the Museum of the San Diego Natural History Society at San Diego, and some pertinent material obtained.

But by far the richest samples of spiny lobster larvæ were returned through the activities and generous co-operation of the California State Fish and Game Commission. These collections were secured by means of a small otter trawl with a spread of about 20 feet, operated from their patrol-boat, the "Albacore," and contained many phyllosomes of large size as well as a number of pueruli. The latter represent the stage intermediate between the phyllosome, the form in which the "lobster" is hatched from the egg, and the definitive form of the adult.

An interesting feature brought out by the collections made by the State Fish and Game Commission was the great off-shore range of the phyllosomes and the depth at which some of them were obtained—as much as 150 miles off shore, and to a maximum depth of 75 fathoms. A phyllosome taken at that depth, some 16 miles off Los Coronados Islands, is shown in figure 44.

Certain incidental shore and tidepool collections were made while at La Jolla.

FIG. 44.—Large phyllosome of the California spiny lobster, *Panulirus interruptus* (Randall).

Fig. 46.—A view of Chimborazo, taken at an altitude of about 12,000 feet. Photograph by George Rose.

Fig. 47.—A view of the Chanchan Valley looking west from Huigra. Photograph by George Rose.

Three months were devoted to work in Ecuador and very large collections were made, including about 6,000 botanical specimens, 100 jars of fruits, seeds, and plant products preserved in formalin. Several hundred packets of seeds, a number of wood specimens,

FIG. 48.—Giant cactus plant, apparently undescribed, which is very common in the Chanchan Valley. Photograph by George Rose.

samples of cinchona-bark and small collections of fishes, frogs, shells, and other zoological material were obtained. George Rose, who went as photographer, made about 260 negatives of landscapes and plant subjects.

FIG. 51.—Detail of bamboo boards. This giant bamboo is much used in the construction of houses and fences in the low country along the coast of Ecuador. Photograph by George Rose.

FIG. 52.—A view of the Quinta Normal at Ambato, the first Agricultural Experiment Station to be established in Ecuador. Augusto N. Martinez is director. Abelardo Pachano, Professor of Agronomy, was educated at Cornell University. Photograph by George Rose.

A

Two sections were made from the coast across the western range of the Andes to the interior Andean Valley; one in the south from Santa Rosa to Loja and the other near the center of the country from Guayaquil to Riobamba. A longitudinal section was made down the Andean Valley from San Antonio to Loja. This last section was over the route followed by Alexander von Humboldt at the beginning of the eighteenth century. Many of the plants collected by him on this memorable journey were recollected.

Figures 45 to 56 show the nature of the country, some unusual types of vegetation, the class of buildings, market scenes, and native inhabitants.

BOTANICAL FIELD-WORK IN THE SOUTHWESTERN UNITED STATES

During the month of August, 1918, Mr. A. S. Hitchcock, systematic agrostologist of the Department of Agriculture and custodian of the section of grasses of the Division of Plants in the U. S. National Museum, visited Arkansas, Oklahoma, Texas, and Colorado for the purpose of studying the grasses. In Arkansas, Oklahoma, and eastern Texas the season was unusually dry and hot. As the grasses were in an unfavorable condition for study little time was spent in these states. Collections were made at Fayetteville and Pine Bluff in Arkansas, Stillwater in Oklahoma, and Fort Worth in northeastern Texas. At Amarillo in northwestern Texas the season was more favorable and the grasses were in good condition for study.

Amarillo is situated in the midst of a plain and the flora is characteristic of much of the Great Plains region of the western parts of Texas and Kansas, and of the eastern parts of New Mexico and Colorado. Grasses form the dominant vegetation, and the collection here represented 30 species. Buffalo grass (*Bulbilis dactyloides*) forms patches of sod, but most of the species are bunch grasses and do not form a continuous covering to the soil. The most common are the grama grasses (*Bouteloua hirsuta* and *B. gracilis*) and the needle grasses (*Aristida longiseta, A. purpurea,* and *A. wrightii*). An interesting species (*Eragrostis barrelieri*) was found here in small quantity, evidently being a newcomer. The species is a native of southern Europe and appeared a few years ago in southern Texas, the first collection being made in 1894 by A. A. Heller at Kerrville. In 1897 J. G. Smith collected it at the same place and also at Llano.

In 1902 Professor Tracy found it at Abilene. In 1910 the writer collected the species in several localities (Big Spring, Kerrville, Brownsville, San Antonio, Kenedy) and observed it to be a common weed in lawns and along streets. In time the species will probably spread over a much wider area.

Several days were spent in the vicinity of Long's Peak, Colorado, the headquarters being Long's Peak Inn. This is reached by rail from Denver through Boulder to Ward and by stage northward to Estes Park, Long's Peak Inn being one of several hotels in the park. The hotel is at an altitude of about 9,000 feet. To the east are two peaks, the Twin Sisters, rising to a height of about 11,500 feet. Long's Peak lies a little south of west, in an air line about four and

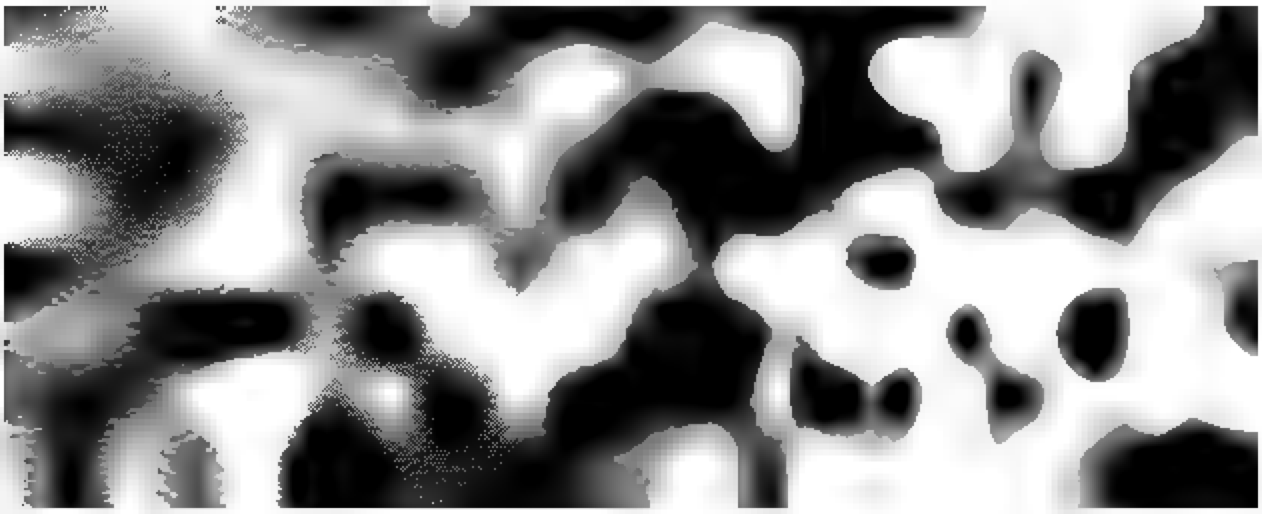

FIG. 57.—A view of Long's Peak from the summit of Twin Sisters. Long's Peak is the central dome, the summit of which is 14,255 feet. Chasm Lake lies at the base of the cliff below the snow bank.

one-half miles, its summit reaching an altitude of 14,255 feet, over 100 feet higher than Pike's Peak, the best known of Colorado's mountains. A short distance to the northwest is Estes Cone, a symmetrical, isolated peak about 11,000 feet high.

One trip was made to the summit of Twin Sisters and another to the summit of Long's Peak. The second trip was made in company with Titus Ulke and Mr. Babcock, the latter a forest ranger kindly placed at our service by the superintendent of the park. Mr. Babcock had ascended the peak many times, having acted as a guide to tourists. His efficient aid was greatly appreciated.

The party set out in the morning for Timber Line Cabin (11,000 feet) and spent the afternoon in observations at Chasm Lake and

FIG. 58.—Estes Cone as seen from Long's Peak Inn. This regular peak is about 11,000 feet high. The shrubs in the foreground are alders along a stream, the conical trees are Engelmann spruce, the more irregular dark trees are lodgepole pine

FIG. 59.—The summit of Long's Peak from Chasm Lake. A part of the lake is shown at the lower right-hand corner. The rounded dome in the center is the summit. The precipice is about 2,000 feet high.

vicinity. Chasm Lake lies at the foot of the east face of Long's Peak, which rises above it, a sheer precipice of over 2,000 feet. A beautiful and well-marked lateral moraine leads away to the east of the lake. On the morning of the second day the ascent of the peak was commenced and the summit was reached about noon. Fortunately the weather was clear and the whole surrounding country lay in plain view for many miles, even Pike's Peak being distinguishable, nearly 100 miles to the south.

The timber-line is at approximately 11,000 feet. In this vicinity the trees are stunted by the force of the winds and can develop only

FIG. 60.—A heavy rock near Chasm Lake, probably transported by glacial action and left supported by four small stones.

in the lee of rocks and hillocks. It is not uncommon to find a dense growth of pine or spruce reaching up to the level of a protecting ledge, but prevented by the force of the wind from extending above this level.

The forest on the slopes of the mountain consists mainly of four species, the aspen, the Englemann spruce, and two kinds of pine. The aspen (*Populus tremuloides*) is a deciduous tree with smooth light green or nearly white bark, found up to about 10,000 feet. The Engelmann spruce (*Picea engelmanni*), a beautiful conifer with a tapering top, is common over all the upper stretches of the mountains. The lodgepole pine (*Pinus contorta*) is the common pine

FIG. 63.—A single tree of lodgepole pine (*Pinus contorta*), aspens in the background.

FIG. 64.—A stunted pine (*Pinus flexilis*) near Timber Line Cabin. The tree, now many years old, is sheltered from the severe winds behind a rock, but above the level of this it cannot extend. A stunted growth of this kind is known to the ecologist as krumholz.

FIG. 67.—Green gentian (*Frasera speciosa*), a stately plant about four feet high. Common from 7,000 to 10,000 feet.

FIG. 72.—Seminoles in Boats.

FIG. 73.—Seminole Types.

At the western side of Pando there are the remains of a fine though small palace or temple. Although it is only about 85 feet square, this little building is remarkable on account of the attractive arabesque patterns made in the stucco coating of the walls. (See fig. 74.) The western end of the main room was provided with a platform raised some 3 feet above the rest of the floor. Behind this there was a passage (fig. 75) which led to other apartments. It is not now possible to know exactly what sort of roof there was, for the wind has eroded the tops of the walls and signs of roof beams or joists are no longer visible. The present inhabitants of this

Fig. 75.—Corridor of the small palace at Pando. A dwelling of present inhabitants in the background of the picture.

ruin are a wretched Indian family who live in the crude shelter made of burlap and old gasoline cans seen in figure 75.

From Lima Mr. Means went to Arequipa and La Paz and while at the latter place he visited Tiahuanaco. There are, besides, several related sites in the region, notably Pumapuncu Llojepaya and Viacha, which are almost unknown. The chief collections studied at La Paz were those of Messrs. Federico Diaz de Medina, Agustín de Rada, Arturo Posnansky, and that of the Museo Nacional (directed by Sr. Jáuregui.)

From Bolivia, Mr. Means went to Piura in northern Peru. There he hoped to find much archeological material, but various sorts of grave plunderers had preceded him, and archeological sites are apparently few. The collections of Dr. Victor Eguiguren (of Piura) and of D. Luis Elias y Elias (of Morropón) were examined.

FIG. 77.—Circular and D-Shaped Towers in McLean Basin Ruin. Photograph by J. Walter Fewkes.

Sand Canyon, one of the northern tributaries of the McElmo, contains several prehistoric buildings which have not hitherto been described, but offer possibilities for future research. Among these are well-made cliff-houses, one of the best preserved of which is shown in figure 83. There is another house (fig. 84) in a ceremonial cave, consisting of a single circular kiva of the Mesa Verde type

Fig. 79.—D-shaped tower, McLean Basin, Utah. Photograph by J. Walter Fewkes.

surrounded by rectangular rooms, occupying the whole floor of the cavern. This building is a unique example of a pueblo of the single unit type situated in a cave. A remarkable feature is the existence of walls of a more modern kiva built inside those of an older chamber, resembling in this respect one of the kivas of Spruce Tree House, on the Mesa Verde National Park. Another unusual ruin in Sand

Fig. 80.—Model of Towers in McLean Basin, Utah.

Fig. 81.—Holmes Tower, Mancos Canyon, Colorado.
Photograph by T. G. Lemmon.

Canyon is a wooden scaffold in a cave like that of Scaffold House in the Navajo National Monument.

There are several other cliff-houses in Sand Canyon all of which resemble in the structural features of their kivas those of Mesa Verde and Chelly Canyon, but differ from those of the Upper Gila and Salt rivers.

The group called cliff-dwellings, from the fact that they occur in caves or cliffs, was formerly universally recognized as a division in

FIG. 82.—Sand Canyon Tower, Colorado. Photograph by T. G. Lemmon.

a classification of southwestern ruins. It is evident from enlarged knowledge of the architectural forms of these buildings that the only difference between the so-called cliff-dwellings and others found in the open is their site; structurally they are identical and were evidently constructed by the same people. Some cliff-dwellers were related to the Pueblos, but all cliff-dwellings were not built by people

FIG. 84.—Ceremonial cave, Sand Canyon, Colorado. Photograph by T. G. Lemmon.

FIG. 85.—Fish Creek Canyon, Apache Trail, Arizona. Photograph by Mark Daniels.

It was found that the artificial heaps of stones in the Montezuma Valley and the mesa north of the McElmo are arranged in clusters forming villages like the Mummy Lake Group on the Mesa Verde. All component mounds of a group are the remains of buildings constructed on the same general plan, their size depending on the number of component unit types or kivas. The characteristic form of a unit type with four kivas is shown in Far View House, illustrated in the account of field-work for 1916. There is every reason to suppose that a like clustering of small pueblos into villages occurs on the Mesa Verde, throughout Montezuma Valley, and on the summits of the mesa north of the McElmo.

Fig. 90.—Mound on Santa Fé Ranch, near Topila, Vera Cruz. Courtesy of Drs. Adrian, Staub, and Mr. Muir.

Chronologically arranged, the classification of ancient habitations in the McElmo, adopted as a result of recent field-work, is as follows: (1) Single houses with walls constructed of rude cyclopean masonry, stone slabs or megaliths set on end. (2) Villages in cliffs or in the open, composed of units of the same structure in clusters or consolidated, each unit being composed of a characteristic circular kiva with vaulted roof embedded in rectangular rooms. Towers and great houses, either isolated or united, are sometimes found in this group, which is a prehistoric type, now extinct, the highest attained by the Pueblos. (3) The mixed type of architecture, found in modern pueblos, has no embedded circular kivas, and marks an epoch of decline in house building largely due to admixture or influence of other tribes.

Aztec Spring Ruin in the Montezuma Valley will probably, in the future, become of considerable popular interest, as the owner, Mr. Van Kleeck, of Denver, has generously offered the site to the Public Parks Service for permanent care by the United States Government.

FIG. 91.—Side view of painted clay drinking vessel with hollow handle. Tempoal, Vera Cruz. Courtesy of Drs. Adrian, Staub, and Mr. Muir.

In order to be in a position to give expert advice on the desirability of accepting this generous offer, Dr. Fewkes revisited Aztec Spring Ruin and reports that it is not only one of the largest and most typical prehistoric villages of the Montezuma Valley, but also recommends that it be excavated and repaired.

ANTIQUITIES OF THE GULF COAST OF MEXICO

Several years ago (1904-1905) Dr. Fewkes made a preliminary trip to the Mexican states, Vera Cruz and Tamaulipas, for the purpose of tracing the relationship of the Totonac and Huaxtec Indians along the Gulf coast to the mound builders in the United States, or

FIG. 92.—Front view of painted clay drinking vessel with hollow handle. Tempoal, Vera Cruz
Courtesy of Drs. Adrian, Staub, and Mr. Muir

across the Gulf of Mexico to the prehistoric inhabitants of Porto Rico and Cuba or other adjacent Antilles. A fair beginning was then made in this direction and the results were published in the Twenty-fifth Annual Report of the Bureau of American Ethnology. He has again taken up the problem, and through the kindness of friends has collected additional data bearing on these questions.

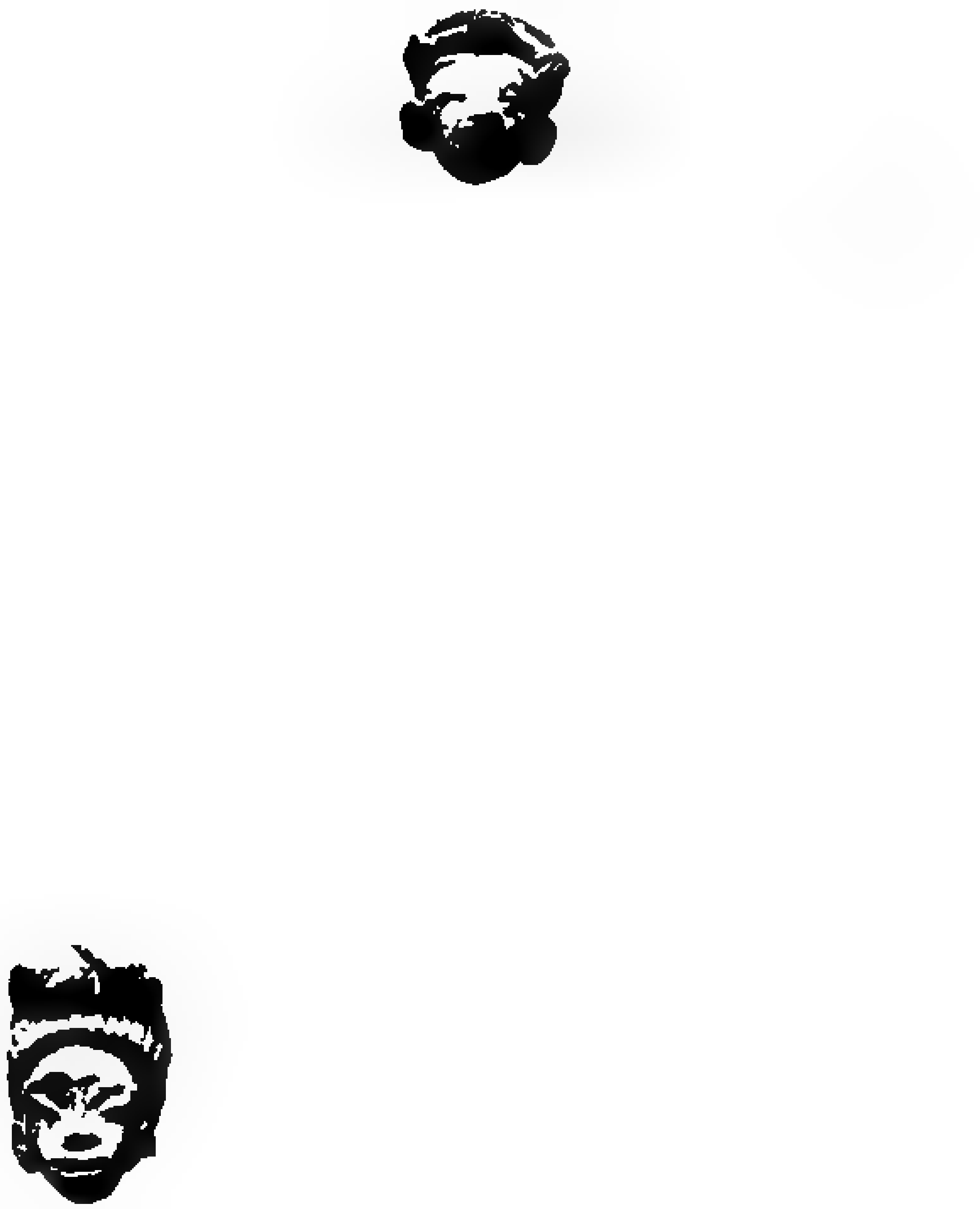

FIG. 93.—Clay heads, Tampico, Mexico, U. S. National Museum. The two outer heads in the middle row are from San Juan Teotihuacan, Valley of Mexico. Photograph by De Lancey Gill.

The general appearance of ruined buildings or mounds, locally called "cuves" (fig. 90), situated along the Panuco River, Mexico, recalls that of Louisiana mounds, but unlike them, as a rule, they were faced with stone work, absent in all the mounds of the Mississippi Valley. On top of the Mexican mounds there stood a stone superstructure or temple, but the mounds show no indication of walls within, as is the case with artificial stone heaps in Colorado,

Fig. 94.—Stone slab from the Cerro Cebadilla, U. S. National Museum. Courtesy of Drs. Adrian, Staub, and Mr. Muir.

Utah, Arizona, and New Mexico. These remains and pottery objects (figs. 91, 92) found near them are ascribed to the ancient Huaxtec Indians.

The figurines (fig. 93) made of burnt clay that have been exhumed from these mounds recall in a distant way the clay heads found in the Antilles, but more closely resemble those of the mainland. The ancient pottery of the inhabitants of the valley of the Panuco is allied

Fig. 95.—Stone Idol, Panuco, U. S. National Museum. Photograph by De Lancey Gill.

FIG. 96.—Stone Idol, Tampico, U. S. National Museum. Photograph by De Lancey Gill.

to the archaic ware of the Valley of Mexico. Burnt-clay heads from the Huaxtec region distinctly resemble archaic heads from the Valley of Mexico, two of which, from San Juan Teotihuacan, are here figured (fig. 93).

A flat stone slab (fig. 94) from Cerro de Cebadilla in the Panuco region, now in the U. S. National Museum, was part of the facing of one of these cuves, or possibly one of the bounding stones of a ball court used by the Huaxtecs, and recalls prehistoric Porto Rican remains called *juegos de bola*. The stone idols from the Huaxtec

FIG. 97.—Stone Idol, Jopoy, Tamaulipas, U. S. National Museum. Photograph by De Lancey Gill.

region are characteristic, as seen in the hitherto undescribed specimens (figs. 95, 96, 97). The representation of a conical hat found on one specimen (fig. 98) would seem to indicate the same god as that figured and identified by Sahagun as Quetzalcoatl, the Plumed Serpent. The art shown by figure 100 recalls that on stone collars and three-pointed stones, but the enigmatical objects from Haiti and Porto Rico are not found in North, Central, or South America. Possibly the stone collars of the Antilles may be idols embodying the insular conception of a being corresponding to the Bird Snake Dragon of the Mayas.

FIG. 98.—Idol with pointed cap, Panuco, U. S. National Museum. Photograph by Delancey Gill.

FIG. 100.—Stone idol, Tampico, U. S. National Museum. Photograph by De Lancey Gill.

Left side Right side Back

FIG. 101.—Stone idol with incised decorations from Consuelo, San Luis Potosi. Courtesy of Drs. Adrian, Staub, and Mr. Muir.

notes and maps, Dr. Fewkes has in preparation an extensive memoir on the antiquities of the oil fields of Mexico, which will supplement and in some respects enlarge our knowledge of the archeology of that region.

ARCHEOLOGICAL EXPLORATION IN ARIZONA

The exploration in Arizona under the auspices of the bureau, by Dr. Walter Hough, curator of the Division of Ethnology, U. S. National Museum, was productive of interesting observations on

Fig. 102.—Cliff House, Oak Creek (White Mt., Apache Reserve).

prehistoric ruins, many of which are undescribed. Owing to the scarcity of labor on account of the draft the exploration was confined to a reconnoissance of the ruins in the vast region lying west of Fort Apache and including the Tonto Basin Forest. The work covered a portion of this area and required 500 miles of travel by various means of locomotion. Much of the country traversed is very difficult, being broken by deep canyons eroded in the slopes of the great Mogollon escarpment, known locally as the "rim" or "mountain," a tremendous geographic feature of dominant importance, in which the rivers of southern Arizona take their rise.

FIG. 103.—White Mountain Apache House.

FIG. 104.—Great Kiva, near Fort Apache, Arizona.

The art of the cliff-houses does not appear to correspond with that of the neighboring open-air pueblos so far as pottery and some other things are concerned. It is probable that the cliff-house sites in this region represent the habitations of a small house people. It is also possible that there were spread over the Pueblo region tribes that never formed the habit of coalescing into compact pueblos. Much that has been discovered substantiates this theory.

A rather unusual evidence of the age of a pueblo was furnished by a juniper 126 inches in circumference growing in the house mass of a ruin near Blue House Mountain in the western portion of the Apache Reservation.

Near Fort Apache a ruin was observed which had as a prominent feature a rectangular depression 45 by 51 feet square and at present 5 feet deep and occupied by three large pine trees (fig. 104). This great construction is believed to be a kiva and is evidently like those described on the Blue River and Upper San Francisco at Luna, New Mexico.

In connection with the Apache Indians with whom Dr. Hough was thrown in contact during this exploration, it may be said that notable changes have taken place among them since 1901, when he visited them. There is little except their habitations (fig. 103) to connect them with their former life, all traces of native costume, etc., having disappeared. The Apaches are on the whole prosperous and contented and have an intelligent appreciation of their duties to the United States (fig. 104).

ARCHEOLOGICAL RECONNOISSANCE OF NORTHWESTERN ARIZONA

Late in April, 1918, provision was made by the Bureau of American Ethnology for a brief archeologic reconnoissance of that little known section of Arizona lying north of the Colorado River, and Mr. Neil M. Judd, of U. S. National Museum, was detailed for the purpose.

From Kanab, Utah, Mr. Judd proceeded with pack mules on a route lying southeastward over the northern portion of the Kaibab National Forest to House Rock Valley, thence southward across North, South, and Saddle canyons to the Walhalla Plateau, known locally as "Greenland." He examined a large number of low mounds bordering the rim of this promontory or scattered over its timbered ridges.

FIG. 108.—Looking across the Grand Canyon from ruins near the head of Clear Creek, Walhalla Plateau.

FIG. 109.—Cliff village in lower Saddle Canyon, with the Rio Colorado in the distance.

Many mullers and metates lay promiscuously about, and two of the latter were pitted on the grinding surface, showing secondary use as mortars. Flint chips and projectiles seemed unusually numerous, but potsherds, although of the customary types found on "Greenland," were surprisingly few in number.

Cliff-houses are not so plentiful as might be expected in the breaks bordering the Walhalla Plateau and these are, almost without exception, small single-room storage cists built by the inhabitants of the open houses among the pines and back some distance from the rim. Many of these cists have been occupied recently as shelters by white hunters—the smoke stains on the cave roof will not be confused with those left by aborigines. Dwellings protected by shallow caves are not unknown, however, and, although small, they add much to the picturesqueness of the country and to the less easily understood ruins of the mesa tops. Cliff-dwellings not visited during the recent reconnoissance are reported along the trailless ledges far below the floor of "Greenland"; others are know to exist in the "sand hills" and the red ledges of Pahreah Plateau. The difficulty of studying these remains is greatly enhanced by the infrequent sources of water supply and lack of forage for saddle and pack animals. As in other sections of the Southwest, the prehistoric dwellings are not always to be found in the vicinity of existing springs or water pockets.

ARCHEOLOGICAL STUDIES IN CENTRAL MISSOURI

Mr. Gerard Fowke, a collaborator of the bureau, made a reconnoissance in the Ozark region of south central Missouri. The purpose of the work was to locate and examine, as far as was feasible, all archeological remains, but with particular reference to caverns which afford evidence of having been used as places of shelter in prehistoric times. As the area in question includes the principal cave region lying east of the divide which separates these streams from the drainage basin of White River in the southwestern part of the State, a careful investigation was desirable.

It appears that Phelps and Pulaski Counties were centers of aboriginal population. There are many caverns, large and small, a majority of them showing abundant evidence of their former occupancy. Potsherds, broken animal bones, mortar stones, flint chips and spalls, broken implements of stone, bone perforators, and especially mussel shells, may be found under the present floors of the caves, and excavation shows them to continue to a considerable depth, usually to the bottom of the fine, loose, cave earth which rests

upon the original clay or rock bottom. In many of the caves, however, this bottom cannot be reached, as water interferes with the digging, but ashes abound to whatever depth excavated. In a cave on Gourd Creek, 12 miles southwest of Rolla, this material formed a mass, almost solid, to a depth of 7 feet or more, and even then its limit was not reached; but no greater depth can be reached until a ditch is dug to the outside of sufficient depth to drain off the water which has accumulated from interior drainage. Goat Bluff Cave, facing the Gasconade near the line between Phelps and Pulaski Counties, 4 miles west of Arlington, shows a similar condition. Many of the caverns have a large amount of talus and other débris about the opening which sometimes makes entrance difficult; others have earth floors which are many feet in depth, with no refuse material near the present surface, although it extends down the slope on the outside. While the larger caverns would have sheltered more persons and consequently may yield a larger number of artifacts, it is not to be expected that traces of very ancient residence will be found in them in the same abundance as in smaller caves. A cave with a narrow entrance to the interior could be more readily defended by its inmates than one where the passageway is larger and the interior more accessible. It would therefore be natural to conclude that a smaller cave would be inhabited longer than a larger one, and so contain more ancient remains.

Passing in any direction from these two counties, caverns continue, though they gradually diminish in number, and while many of these are suitable for shelters or permanent homes, fewer of them have the usual indications of occupancy. With the changing elevation of the cave-bearing strata, due to the dip of the formations, a smaller number of them are as well adapted for shelters. It seems useless to investigate anything beyond the limits reached in these researches.

In addition to the residential caverns along all the streams in these two central counties there are numerous village sites on the level bottom lands. Flint implements and chips are very abundant; pottery fragments less common except in a few places where it would appear that vessels have been manufactured; axes or hatchets are rather rare; other objects, such as mortars and pestles, have not been reported, probably because they are overlooked in the search for "arrows"—a general term, including all edged or pointed flints—which are very plentiful, though usually not smoothly finished. Several large mussel shells, found in the caves, are perforated for attachment to a handle, for use as hoes.

Very few of the caverns visited along the upper Current and upper Meramec Rivers are adapted for shelters, being damp or with small openings which shut off light from the interior; or difficult to reach; or at a distance from water. This is also true of the caverns along the lower Osage and lower Gasconade. The best field for research, however, is situated in Phelps and Pulaski Counties, where scores of caverns not only promise good material, but also are of sufficient depth to have stratification containing the handiwork of successive populations.

No aboriginal burial places have been discovered in level bottom lands, though many must certainly exist, when consideration is given to the evidences of numerous villages and long periods of occupation.

Cairns are found on nearly every ridge, especially on points which overlook streams or valleys. Nearly all were the ordinary conical or dome shape, formed by throwing stones over a grave, and are not at all distinctive, resembling in this respect similar burial places in various parts of the country. Two types, modifications of a single plan, were discovered, however, which have not been observed elsewhere. The graves in these are indicated by stone walls forming an enclosure as nearly square as the skill of the builders would permit. In one form, only a single row of flat stones was laid, and the grave, including a narrow space around the outside of the wall, was covered with stones, so that the pile outwardly resembled the ordinary cairn. In the other form this wall is carried up several rows, making a structure like a cellar wall or the foundation of a house. The space within this was filled with stones thrown in loosely, but none were placed against the outside. This latter type differs from the earth-covered stone vaults along the Missouri River where the inside of the vault is laid up as evenly as possible, no attention being paid to the outside; whereas, in the former, this feature is reversed.

FIELD-WORK AMONG THE KIOWA

From July to October inclusive, Mr. James Mooney, ethnologist, continued his field investigations of the Peyote cult and Kiowa heraldry among the Kiowa and associated tribes of Oklahoma.

The heraldry investigation relates particularly to the confederated Kiowa and Kiowa Apache, and involves a study of the origin, history, decoration, myths, and ceremonial regulations in connection with the shields and heraldic tipis formerly existing in the two tribes (there being approximately 250 shields and 50 decorated tipis), with incidental attention to the tribal systems of genealogy, heredity, and medicine, together with the warrior organization and

Fig. 110.—Temkwa, Chief Priest, Native Peyote Religion, Comanche Tribe.

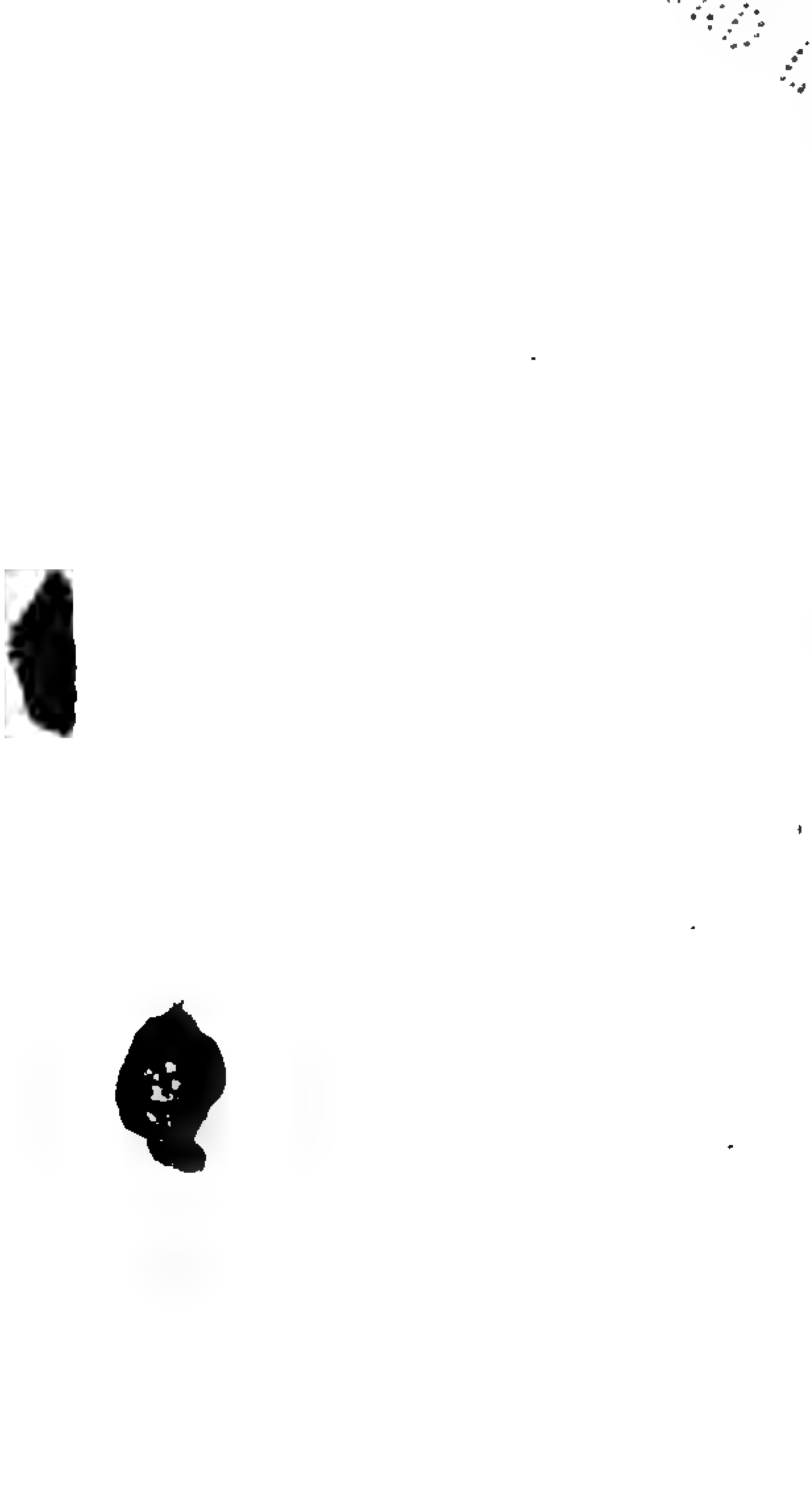

FIG. 111.—The Peyote (*Lophophora williamsii*): whole plants, green top, and dried "buttons." About one-half actual size.

native religion. Its use in both connections among the tribes of Mexico was noted by the earliest Spanish writers after the Conquest and by such later investigators as Lumholtz and Fuchs. It was noted in Texas as early as 1760.

In continuation of his study begun years ago, before the Peyote religion had reached its present high development or territorial extension, Mr. Mooney, on invitation of the tribes, transmitted by delegates from the Councils, made observation of the ceremony and of the medical use of the plant, and had filled out a number of individual questionnaires relating to the same subject, among the Kiowa, Comanche, Apache, Caddo, Cheyenne, and Arapaho, being everywhere received with the most generous hospitality and given every opportunity for observation and investigation, by reason of his long-standing friendship with the tribes and his known interest in the subject.

FIELD-WORK AMONG THE IROQUOIS

Mr. J. N. B. Hewitt, ethnologist, of the Bureau of American Ethnology, resumed his work in Ontario, Canada, on the textual and literary criticism of the many texts which he had previously recorded relating to the establishment of the Federation or League of the Five Tribes (or Nations) of the Iroquois, and especially to the organic institutions of this league. By the accession of the Tuscarora in 1722 these Indians became the Six Nations of the Iroquois.

The larger and more detailed part of these texts was dictated by his late friend, the blind Seneca federal chief, John Arthur Gibson, one of the best-informed ritualists and expounders of the principles and the institutions of the so-called League of the Iroquois; the remainder, consisting of differing versions of the matter just mentioned and also of much additional and supplemental material in the form of texts, was recorded from the dictation of other competent informants, among whom may be mentioned the late Onondaga federal chief, John Buck, who was at the time of his death the federal Fire-Keeper; the present Cayuga federal chief emeritus, Abram Charles; and Chief Prophet Joshua Buck, all versed in the varying traditions of the motives and plans of the founders of the League or Federation and the decrees and ordinances promulgated by them for its establishment.

The diction is largely that of the forum. The notional terms employed are those of statecraft and ritualism—the language of statesmen and stateswomen and prophets of that earlier time, who even then had measurably clear visions of institutions of to-day,

FIG. 114.—Red-faced mask of a Wind God. A deity of Disease and the East.

FIG. 115.—Black-faced mask of a Wind God. A deity of Disease and the West.

such as the recall, the initiative, the referendum, woman suffrage limited to mothers for the election of nominees to chiefships, and a colonial policy. It may be added here that the men had no voice in the nomination of chiefs.

Certain words occurring in Iroquois texts show that the laws and the rules of procedure among the Five Iroquois Tribes were not the decrees of an autocrat or tyrant, but rather were the formulated wisdom of a body of peers, who owed their official positions to the suffrages of those who owned the titles to them, and that the form of government was a limited democracy, or, strictly speaking, a limited gyneocracy.

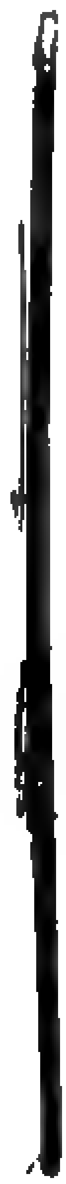

FIG. 116.—Lacrosse clubs of the Iroquois. A bow with arrows.

In this manner the following matters were studied and analyzed: The law defining the position, the powers, and the disabilities of a chieftainess, or Goyānegō'nā'; the law defining the position, the powers, and the disabilities of the tribal chiefs, and of the federal or *Royaner* chiefs of the league (or Extended Lodge), and the manner of their nomination, installation, and removal for cause; the law of the extinction of the ohwachira (or uterine family), having federal or Royaner chief titles, called Ē^{n}yoñdoñgwe'do'k'dĕ^{n}', *i. e.*,

they will run out of persons, and so no more men will be available for candidates for chiefships; the law defining the position, the powers, the disabilities, and the authority of the Onondaga chief, De'hadodā''ho'; and of his co-tribal Royaner chiefs; individually and in their collective capacity of Federal Fire-Keepers; the law of the method, the limitations, and the effect of the action of these Fire-Keepers in confirming, or in referring back for cause for review, to the Council of their peers, any of its acts, whether unanimous or not; the law limiting suffrage for the nomination of chiefs to the mothers in the clans; and the law recognizing descent of blood and fixing the status of persons in the female line; the law of the sacredness of the lodge and of private property; the law of hospitality, good neighborhood, and good fellowship; the law of murder, and of rape, and of highway robbery; the law of the police, or the regulation of the internal affairs of the league, symbolized by the Long Wing of the Gull and the Staff which were placed in the hands of the great federal chief, De'hadodā''ho'; the law of the domestic relations; the law of hunting and fishing; the law of planting and the protection of the crops; the law fixing daytime and the place for holding the sessions of the Federal Council and for the demeanor of the Royaner or federal chiefs at such sessions; the law defining the position, the powers, and the limitations of the Merit, or the so-called Pine-Tree chiefs; the law for the adjustment of homicide, obviating the former *Lex talionis;* the law of homicide by a Royaner or federal chief; and the law of the Union or Federation of Clans and of Lands (or Peoples), with an extensive explanatory preface.

A number of other rituals and traditions of the Iroquois were analytically studied, and Mr. Hewitt also collected a number of Museum specimens, including a very fine wooden mask of a Disease God, painted red; it is a work of art. Some of these are illustrated in this paper.

FIELD-WORK AMONG THE CHOCTAW AND CATAWBA

Dr. John R. Swanton, ethnologist, of the Bureau of American Ethnology, was in the field from the middle of April to the end of May, 1918. On leaving Washington he went immediately to Charenton, Louisiana, where he spent about one week amplifying his grammatical sketch of the Chitimacha language already prepared, and clearing up some doubtful points which had developed during its composition.

After completing this work he proceeded to Philadelphia, Mississippi, in order to ascertain something regarding the present con-

Fig. 117.—Nanih-waya, or "Mother Hill" of the Choctaw.

dition of the Choctaw Indians in that neighborhood, the descendants of those who remained in their old country after the greater portion of the tribe had emigrated to what is now Oklahoma. On the way he stopped at Bay St. Louis to visit a small band of Indians living in the country north of that place. He learned that this was a band of the Sixtown Choctaw, the southernmost division of the Choctaw nation, but that all of the old people were dead and practically nothing regarding their ancient manner of life was known to the survivors.

Near Philadelphia (Mississippi) remnants of three Choctaw bands or clans are still to be found, and in the few days spent in interviewing them—this being merely a reconnoissance—a few interesting data regarding their social organization and former customs were secured. A visit was also made to the famous Nanih-waya, or "mother hill," of the Choctaw, where, according to some versions of the Choctaw origin legend, the ancestors of this tribe emerged out of the earth. This is an artificial elevation of considerable size in the midst of a fairly level tract of country, surrounded partly by Nanne Warrior Creek, so named from the hill, and partly by a low earthen rampart, traces of which are now barely visible. Several photographs of this hill were taken.

The remainder of the time, until the end of May, was devoted to a study of the Catawba language on the Catawba reservation near Rock Hill, South Carolina. Early in the eighties the late Dr. A. S. Gatschet, of the Bureau of Ethnology, collected a vocabulary and other linguistic material on the reservation, and recently Dr. Michelson spent a short time there studying the people and their language, but our knowledge of it is still very imperfect and any additional material is sure to be of value. Although fairly well known to about 20 persons, this language is no longer in common use and few Catawba retain it in anything like its ancient purity. Its peculiar value consists in the fact that it is the only surviving dialect of the eastern Siouan group and that by which the other Siouan fragments from the same area must be interpreted. It appears to be the most aberrant of all the Siouan dialects and to contain features of great value in tracing the evolution of the entire stock. Dr. Swanton was able to collect considerable material, principally detached words and phrases, also a slight amount of textual material, being assisted very much by Dr. Gatschet's manuscript vocabulary. Some notes of general ethnological character were also secured, but the tribe has lived so long in close contact with white people that it is doubtful whether much of this is purely aboriginal.

took place, a movement that made it possible to suspend the tedious ceremonial forms that were hitherto observed when organizing a war party. A single gens or a number of gentes were now empow-

FIG. 118.—Osage Warrior with Pictured War Symbols on His Body.

ered to organize war parties. A war party organized by the new method was called Tsi'-ga-xa Do-do^n, a name which may be freely translated "Outside the (Sacred) House." With this new depar-

knife between its point and the pipe design, terminating behind the shoulders (fig. 118).

The woman, upon whom depends the continual existence of the tribe, was no less honored than the warrior who risks his life for the people. Upon her forehead, chest, back, arms, hands, and the lower part of her legs are pictured, in conventional designs, the sun, stars, the earth, the powers from whose united force proceed life in all its manifold forms. The lines running down from her shoulder to her

FIG. 119.—Osage Woman with Conventional Symbols Pictured on Her Body.

wrist symbolize the "paths of animals," in reality, life descending from the sun and the stars to the earth, represented in the conventional design of a spider pictured on the hand (fig. 119).

When the fourth stage of the tribal government was completed this rite was transferred to the Poⁿ'-ka Wa-shta-ge chief and also added to the rite formulated for him. The translation of the story of this combined rite, as given in full by Wa-xthi'-zhi, is in process of completion. It contains 31 wi'-gi-es (recited parts), songs, diagrams, illustrations, charts, and text.

MATERIAL CULTURE AMONG THE CHIPPEWA

During the summer of 1918 Miss Frances Densmore, of the Bureau of American Ethnology, visited four localities and her work included a wide field of research. The first reservation visited was Fort Berthold in North Dakota. The purpose of this trip was a final consultation with the Mandan and Hidatsa Indians concerning their music

Fig. 120.—Woman placing tobacco in ground before felling birch tree.

to complete her bulletin on that subject. Information on important points was verified, and additional material was secured, especially regarding the musical instruments used by these tribes. Among the latter data was a description of a " double whistle," said to have been used by the Mandans in former times, and a peculiarly decorated drum used by the Goose women's society. A close examination of a similar drum in the North Dakota State Historical Society revealed a trace of this decoration, almost obliterated by age and use. This specimen was kindly loaned by that society for illustration.

FIG. 121.—First Incision in Bark of Birch Tree.

FIG. 122.—Removing Bark from Birch Tree.

of the plains Indians whose earlier home was in what is now western Montana, while the Tanoans are a typically Pueblo division inhabiting the Rio Grande drainage of New Mexico. It is proposed that the linguistic family thus established, including Uto-Aztecan, Tanoan, and Kiowa, be termed Patlan, a name derived from the word meaning " water " or " river " in all these languages.

In August Mr. Harrington proceeded to California to continue his studies among the Mission Indians of the Chumashan region of southern California. It was his good fortune to be able to make most important additions to the Ventureño grammar, securing many old words which it had been impossible to obtain at previous visits and which are most important for throwing light on all the related languages.

A searching ethnological questionnaire was used with the informants, yielding very gratifying results, especially in the field of material culture. Detailed information on ancient dance regalia and the process of preparing native tobacco and its uses was obtained. An adequate description was procured on ancient traps for ground squirrels and other small animals whose names had been given by various informants, but had never been satisfactorily described. Quite a little new and important information on archery was obtained. Mr. Harrington had special success in learning from a couple of aged women the ancient childbirth practices, including a unique description of the method of cutting the navel cord by means of a carrizo knife after the blood had been dried out of the section by the application of warm decoction *pespibata*. A bed of warm coals was made on the floor and a layer of medicinal herbs was placed on top of this, on which the mother and child lay for three days after childbirth. Sociological problems were intensively investigated and new information was gathered, especially on mortuary customs. Likewise, a few old songs, among which is an especially pretty quail song which has the refrain *ka, ka,* imitating the cry of the quail brought out with a peculiar stressed voice. This and some of the other songs doubtless form parts of old cycles, the other songs of which have not been recovered.

Mr. Harrington obtained from Manuel Chura, who was born in 1820, and is therefore nearly 100 years old, much linguistic information, and 15 very rare songs, such as used to be sung at the Indian fiestas in the thirties or forties of the past century. He also obtained several splendid songs from José de los Santos Juncos, who is also nearly a centenarian.

FIELD-WORK AMONG THE SAUK AND FOX

Dr. Truman Michelson, ethnologist, of the Bureau of American Ethnology, spent two and a half months at Tama, Iowa, among the Sauk and Fox Indians. Shortly after his arrival, July 1, the death

FIG. 126.—Some Fox Children in Gala Attire.

FIG. 127.—A Ceremonial Drum used in the Fox " Religion-Dance."

of William Wanatie's son occurred. Dr. Michelson was given tobacco and told to go to the house and be one of those to sit up all night with the corpse. Wanatie is the owner of one of the drums connected with the so-called religion-dance; and the oppor-

tunity to observe the ceremonies was unequaled. A few days later Ella Davenport died, probably of tuberculosis; however, her parents believed that she had been witched, and he was asked to be one of those to watch her grave at night for a number of days, being assured that Indians knew very well that witches were afraid of white people and would not harm them. It appears that Fox Indians believe that if a person has been killed by a witch, the witch will return in the form of a dog, owl, or bear, tap four times on the grave of the deceased, whereupon the dead will come back to life and the witch will then proceed to torture the person by cutting out his or her tongue and stringing his or her heart. He of course embraced the opportunity; and with a few Indians sat up with loaded shotguns for a few nights watching the grave. Unfortunately the witch did not come. After such a favorable opening he seized the occasion to obtain a number of texts written in the current syllabary on the origin of death, the ceremonies connected therewith, etc., which have since been translated. These texts all supplement rather than contradict each other. The grammatical analysis of the text appurtenant to the Owl sacred pack, begun with Edward Davenport at the U. S. Indian School at Carlisle, was completed. A number of texts collected in previous seasons, some appurtenant to ceremonials and the like, and a few folk tales were translated in the course of the summer, as were the personal names of approximately nine-tenths of the entire Fox population.

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ARCHEOLOGICAL INVESTIGATIONS AT PARAGONAH, UTAH

(With Fifteen Plates)

BY

NEIL M. JUDD

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INTRODUCTION

The remains of ancient habitations now visible near Paragonah in Iron County, Utah, comprise but a small remnant of the total number which formerly overlooked the broad Parowan Valley, from the foothills between Red and Little Creek canyons. It is recorded[1] that Dr. H. C. Yarrow, of the Wheeler Survey, observed more than 400 mounds in this vicinity in 1872. The figure given, in itself, suggests a possible exaggeration and yet many ruins were unquestionably razed during the succeeding 20 years as the cultivated fields of the modern community increased in extent. Prof. Henry Montgomery, then of the University of Utah, reports[2] approximately 100 mounds near Paragonah in 1893 and a like estimate is given by Mr. Don Maguire of Ogden, Utah, who conducted excavations at the same time as Professor Montgomery in the interest of the Chicago World's Fair. Less than half of these remained in 1915, when the writer began his investigations for the Bureau of American Ethnology and the number was still further reduced during the next 12 months, leaving a bare half-dozen large elevations in the fields already under cultivation and several smaller mounds in the sage-covered area adjoining. But the largest of these, whose size alone has delayed their reduction, had also attracted earlier investigators and each mound still bears the scars of their several undertakings.

In addition to the above observers Dr. Edward Palmer, of the U. S. National Museum, conducted limited excavations at the same locality during one of his numerous expeditions through southwestern Utah between 1869 and 1877. None of these investigators, however, with the single exception of Professor Montgomery,[3] has published an

[1] U. S. Geographical Surveys West of the 100th Meridian, Capt. G. M. Wheeler, Vol. 1, p. 57. Washington, D. C., 1889.

[2] The Archaeologist, Vol. 2, p. 303, 1894.

[3] *Ibid.*, pp. 303-306.

account of his researches. The writer's own impressions, gained in 1915 and 1916, have been, as yet, but partially recorded,[1] a more detailed report being withheld pending completion of additional investigations. It is obvious, therefore, that the remains of an unusually large number of prehistoric dwellings near the village above mentioned have gradually given way before the advance of agricultural preference and that, notwithstanding the many observations made among them, the ruins have contributed but little to our scanty knowledge of their ancient inhabitants and have left us with only the vaguest understanding of the degree of culture to which their builders had attained.

The present paper finds its origin in a joint expedition undertaken in 1917 by the Smithsonian Institution and the University of Utah, at the request of the latter. The writer had the honor and the pleasure of directing the work, with the cordial cooperation of President John A. Widtsoe and Prof. Levi Edgar Young, of the university,[2] and with the active assistance of Mr. Andrew A. Kerr as their field representative.

It must be confessed that, for the layman, there is but little of the spectacular in the results of the expedition. The student of history, on the other hand, will find much to hold his attention—rude dwellings of earth that seem so thoroughly adapted to their environment and vast quantities of minor antiquities, each of which is its own key to the daily activities and industries of the ancient house builders. Here was a people who came from some distant, undetermined region—a people that established a compact community, with a definite social organization, and then passed on to a new locality where another cycle in their tribal history was unfolded. Innumerable paragraphs might be written from the information at hand and yet,

[1] Smithsonian Misc. Coll., Vol. 66, No. 3, p. 67; No. 17, pp. 103-107.

[2] It should be stated that the successful inauguration and furtherance of the season's undertaking was due largely to the interest and perseverance of President Widtsoe and Professor Young. They first enlisted the aid of the government institution and, thereafter, freely rendered every possible assistance in bringing the work of the expedition to a happy conclusion.

In this place, also, the writer desires to acknowledge his appreciation of the generous spirit in which his numerous Paragonah friends contributed to the success of the expedition and he is especially indebted to Mrs. Martha Jane Openshaw and Mr. Isaac Bozarth who kindly granted the necessary permission to conduct the excavations. The ultimate purpose of science can always be best served by such whole-hearted good will and mutual helpfulness as that which greeted the 1917 party.

at this time, it seems unwise to attempt more than a general survey of the season's discoveries, reserving for a subsequent paper the tempting comparison between the cultural evidence disclosed at Paragonah and that found among ancient ruins in other sections of the Southwest. Likewise, direct reference to previous investigations of the Smithsonian Institution in Parowan and neighboring valleys will be avoided in so far as possible, that the following pages may be devoted entirely to the joint enterprise of 1917. A certain heterogeneity frequently obtains among archeological remains in western Utah—such a confusion and intermingling of like and unlike structures that the entire subject may be explained most clearly in a monograph based upon knowledge gained throughout the vast region in which similar remains occur. The present paper treats of but one small section of that region and the results of 1917 should be considered merely as a single, though highly important, contribution toward final solution of the whole complex question.

EXCAVATION OF THE BIG MOUND

Paragonah was reached early in July and the party at once centered its attention upon an elevation known locally as "the big mound," a huge knoll measuring approximately 225 feet in diameter and 10 feet high. There were several reasons for this selection: (1) It was the largest of those remaining and, notwithstanding the previous removal of the southern one-third and superficial evidence of other excavations, it still promised more perfect examples of architecture and deeper court deposits than adjacent mounds; (2) being in the way of proposed improvements, it was in imminent danger of complete reduction, with final loss of its archeologic contents; and (3) exposure of the house-group which the "big mound" was thought to cover would form a fitting sequel to earlier studies of smaller elevations containing from one to five dwellings, together with their related structures.

The ragged blanket of sage-brush which covered the mound was first cut and burned. Trenches were then begun in several places, in search of walls, floors, etc. The actual work of excavation was done with shovels; teams and scrapers being employed only in removing the earth which had been examined and thrown out by the workmen. This method, although slower, resulted in more extensive collections of small artifacts and insured, also, greater accuracy in tracing the various floor levels and house walls, some of which were determined only with the greatest difficulty owing to their coloration

and to the compact condition of the surrounding soil. When house remains were encountered they were immediately exposed, provided no connecting structures were discovered which required previous attention. Working from one dwelling to another, the entire series was finally uncovered.

Early in the course of the excavations it became evident that in the "big mound," as in other similar elevations, ruins of two distinct types were to be found. These naturally increased in numbers as the work progressed, but the obvious relationship between the two types did not differ materially from that established during former operations. The chief task of the 1917 expedition, therefore, soon resolved itself into an effort to locate all of the more permanent houses and to discover in the lesser structures invariably associated with them any variation from their customary form. The outstanding features of each type are given below, with additional notes on certain individual ruins.

In general, every prehistoric community attracts the student both through its architecture and its lesser antiquities, for the house remains, perhaps more completely than the artifacts found within or near them, furnish a true index to the cultural attainments of their builders. And it is the degree of social and material advancement, as evidenced by such remains and by such artifacts, that enables the anthropologist to assign to any given people its approximate place on the ladder of intellectual progress. In considering the results of excavations in the big mound at Paragonah, therefore, attention will first be directed to the structures occupied by the aborigines and then to the minor objects discovered in connection with those structures.

HOUSE REMAINS

Reference to the ground plan (pl. 1) of the mound under consideration shows a number of adjacent, rectangular rooms and several additional buildings. It will be noticed, also, that some of these rooms appear one above the other, but, even in such instances, there is evidence of a purposeful arrangement and the constant recognition of a previously determined relationship. The fireplaces in the areas contiguous to the rectangular rooms indicate the location of temporary structures, occupied in conjunction with the more permanent buildings. All the fireplaces discovered during the course of the excavations are not shown on the ground plan, for they were found indiscriminately and throughout the entire depth of the mound in such numbers as to render impracticable their proper delineation.

The walls of the quadrangular buildings were constructed entirely of adobe, usually in layers, and averaging about 10 inches in thickness. No complete wall has yet been found, but it is reasonable to suppose that none of these exceeded in height the walls of other prehistoric habitations throughout the Southwest, that is to say, from 4½ to 5 feet. This does not mean, however, that the inhabitants were of small stature, a fallacy which has an unfortunately wide circulation. Small houses were easier to build and they afforded greater protection from the elements; they were utilized primarily as sleeping quarters and for the storage of corn, beans, and other foodstuffs. They were designed chiefly to meet these requirements; the daily activities of their owners being performed mostly out of doors or in the shelter of secondary structures.

Much has been said regarding the manner in which these adobe dwellings were constructed, but it has been pointed out elsewhere[1] that the methods employed were not so complex as has been commonly supposed. The builders required merely an abundant water-supply and the clayey soil of the region. A shallow hole near the site of the proposed house sufficed as a mixing box, into which water was poured as needed; the hole grew in extent and depth as its sides were cut down to furnish additional clay. This was undoubtedly mixed by the bare feet of the workers, a method still employed by modern Pueblo Indians and their Mexican neighbors.

Balls of this mud, worked to a stiff paste, were then thrown on to a prepared area, tracing the outline of the room. Other masses were added and the four walls gradually assumed their desired height. Of necessity these were built up in layers, for the cohesive properties of plastic clay are very low and supporting forms were unknown among the primitive peoples of America. Each layer averaged about 15 inches in thickness and the desert sun soon dried it sufficiently to permit of the addition of a superposed course. The fact that these layers vary in thickness from a few inches to more than a foot may be traced usually to an effort on the part of the builders to maintain uniform levels—an unintentional irregularity in one layer would be corrected in placing the next above it. Mud plaster was ordinarily employed in smoothing the inner faces of these walls, but it is sometimes apparent that the freshly laid adobe was merely dampened with water and surfaced over, obliterating all traces of joints.

[1] Judd in Holmes Anniversary Volume, pp. 241–252. Washington, D. C., 1916.

Working in this way, using their bare hands and with no tools other than crude bone and stone implements, the ancient artisans finally brought the new walls to a satisfactory height. A number of wooden beams were then laid a foot or more apart and across the shorter dimensions of the room; above and at right angles to them, smaller poles were placed, with willows or brush, grass and clay, in succession, completing the roof. The resulting cover was fairly tight, but extremely heavy; it successfully turned most of the winter's storms and required repair only two or three times a year, following the rainy seasons. Windows for the admission of light and air were unknown—aboriginal peoples seldom worried about ventilation or lack of it—and the only entrance to the room was a hole through the roof, an opening which was closed at times by a large, thin stone disk.[1]

The primitive masons of Parowan Valley had adapted to their needs the most available building material of their environment; they constructed houses which met their principal requirements and yet these houses had at least one defect which their builders seem not to have overcome. It is apparent that the roof beams did not protrude far beyond the outer surface of the sun-dried mud walls and consequently furnished scant protection for them. In seasons of rainfall, the water which accumulated upon the flat earthen roof either soaked through or ran off the edges and down the walls. In the latter case, the softened adobe would tend to give way under the weight of the heavy ceiling, causing the walls to collapse. It may safely be assumed that these dwellings were frequently destroyed in this manner, even though the opinion be based entirely upon circumstantial evidence, for many travelers in the Southwest have noticed the disintegration of modern adobe houses through the same agency.

A dwelling once destroyed was probably never wholly rebuilt, although its broken walls may have been partially utilized in the erection of a new structure. Lack of suitable tools made the mere task of removing such wreckage a tedious undertaking. To obviate the necessity for this and yet render the site suitable for a new

[1] The writer has been informed through several sources that the stone employed in making the round doors found so frequently among the Paragonah ruins could have come only from the West Mountains or Kane Spring Hills, 10 miles from the village. Stone of similar texture is unknown elsewhere in the vicinity; the difficulties of its transportation may be appreciated if the reader will recall that these old people had no beasts of burden and that many of the disks weigh as much as 75 and 80 pounds.

habitation, the old walls were pulled down upon themselves, the mass brought to a uniform level, and erection of the substitute structure begun.

In a previous paper,[1] the present writer has briefly described the occurrence of superposed dwellings in mounds excavated at Beaver City, Utah. They, like the ones now under discussion, did not always possess the same floor area as the buildings they replaced. In some instances, one or more walls of the upper house coincided with those of the lower; in others, the long axis of the later dwelling lay at right angles to that of the earlier. The mere position of the new habitation seemingly did not influence its builders so much as the fact that necessity compelled its erection and that preference or social custom influenced its construction on the site of the one destroyed.

The occasional superposition of dwellings adds greatly to the interest of such structures as those disclosed by the 1917 excavations. A few of them, briefly described, may serve not only to indicate the general problems involved, but they may also contribute, in a greater or less degree, to an understanding of their primitive builders. Rooms 16-19, for example, occur in three distinct levels. Numbers 16 and 17 originally comprised a single room, but this was subsequently divided by a partition only half as thick as the main walls. Still later, both houses appear to have been abandoned, although Room 17 may have been temporarily occupied after construction of the neighboring house, number 18. A continuation of the floor level of this latter dwelling extended out over the razed walls of Room 16, 2 feet 9 inches above their inner base.

The length of the upper structure was nearly as great as that of Rooms 16 and 17 combined; the condition of its floor suggests occupancy during a considerable period. For some unknown reason, however, the walls of number 18 were later demolished and Room 19, a building only half as long, was erected above them. Seventeen inches of closely packed building material separated the two floors; the width of the structures was approximately the same, although the walls of the one did not rest directly upon those of the other.

The neighboring houses, numbers 8 to 12, furnish a similar example of superposition. Rooms 9 and 11 were built above the partially razed walls of Rooms 8, 10, and 12. Number 8 was constructed subsequently to Room 10, its floor being approximately 10 inches

[1] Proceedings of the Nineteenth International Congress of Americanists, pp. 119-124. Washington, D. C., 1917.

above that of the latter; Room 12 was erected at the same time and on the same level as Room 10.

The walls of all three first-level houses were entirely of adobe, built up in layers, and smoothed or plastered on the inside. There is no means of determining the length of time each was inhabited, but, after a certain period of occupancy, they gave way to Rooms 9 and 11. Here again the walls of the upper structures do not coincide exactly with those of the lower; their orientation, nevertheless, remains practically the same. The floors in Rooms 9 and 11 had been constructed 3 feet 9 inches above that in number 10 and rested directly upon the irregular chunks of sun-dried adobe which formerly composed the walls of the lower room. Plate 3 illustrates the relationship between the outer west walls of Rooms 8 and 9 and shows the difference in their respective floor levels.

While considering this series of dwellings, attention should be called to certain peculiarities which have not been observed during the excavation of other similar houses. In the outer east wall of Room 8, averaging 36 inches above its base and 12 inches apart, was a row of small holes, marking the former position of as many wall pegs or hangers; additional pegs may have existed in the destroyed portion of the same wall. Holes of this sort in adobe dwellings are really unique; owing to their low position the use to which they were put must remain doubtful. A doorway, 17 inches wide and about 24 inches high, pierced the south wall of this room, it being the only lateral entrance yet observed among the prehistoric adobe dwellings of western Utah. So far as could be determined neither wood nor stone had been utilized in its frame. Room 9, directly above this house, was obviously entered through the customary roof opening.

At the south end of Room 10, in its opposite walls and 20 inches above the floor, were two series of four holes each. Those on the west side averaged 11 inches and those on the east 4 inches from each other. They marked the former position of horizontal poles, built into the walls at the time of their construction and probably formed a rude triangular bunk or shelf. This feature, also, is believed to be unique among prehistoric ruins north and west of the Rio Colorado and, if the conjecture be correct, it represents one of the few examples of built-in benches yet discovered among aboriginal dwellings of the Southwest. Similar series of pole rests were not detected in any of the other Paragonah structures.

Room 31, a third-level house, almost entirely destroyed by earlier excavations, was the only dwelling in the big mound whose floor

consisted of a layer of coarse gravel and water-worn cobblestones, overlaid with adobe mud. Foundations of this character were invariably employed in the houses examined near Beaver City, Deseret and Hinckley, and they occurred frequently in those near Fillmore and Meadow, in Millard County. Excepting this course of small stones underneath the floor the house did not differ from the adobe dwellings described above.

It is to be regretted, of course, that the south one-third of the big mound had been completely razed before the recent expedition began its work. According to local reports, house walls were observed in this position of the elevation, and there are those who insist that circular rooms were also present. The number of these and the number of rectangular dwellings must always remain a matter of speculation; that they were many may be inferred from the total discovered in the remainder of the mound.

ASSOCIATED STRUCTURES

Most observers who have conducted investigations among the mounds of western Utah have noticed the occurrence of lesser structures in the areas immediately surrounding the adobe dwellings. Too little importance has been attached to these remains and their true import seems to have been generally overlooked.[1] The recent excavations at Paragonah disclosed houses of this type in large numbers and it is desired at this time to refer to them, collectively, in order that their real place in the community may be fully understood.[2]

It will be noticed that the more permanent habitations in the big mound are grouped to form, roughly, three sides of a square. The interior of this square was filled with accumulations of camp débris and wind-blown earth, averaging 6 feet in depth. The remains of temporary shelters were found without any semblance of order

[1] In the papers cited above, the present writer made no attempt to elaborate upon the court shelters or their obvious bearing upon the more permanent structures. There is evidence pointing to the fact that the former are older, structurally, than the latter.

[2] It should be stated that plate 1 shows but very few of the lesser structures exposed during the excavations of 1917. They were found in such unexpected numbers and so hopelessly interlocked that it was deemed inadvisable to interrupt the main work while each one was carefully uncovered. The chief characteristics of the type had been determined by the expeditions of 1915 and 1916; equally cautious dissection of the "big mound" did not appear commensurate with the time and expense involved.

throughout these deposits. In one place, above fireplace L, seven distinct levels of occupancy were noted and the layers which supported them frequently merged one into another or disappeared entirely a short distance from the limits of the hut. Careful analysis of these levels and the material separating them leaves the impression that the lesser structures were so easily constructed that their abandonment was effected without great compunction, once their usefulness had ended.

The charred ends of upright posts show that a large proportion of these shelters were destroyed by fire; others may have become so filled with débris and dust that their builders found it desirable to select other quarters. In the latter case, the old hut would have been pulled down and its timbers utilized in the new structure, leaving the other materials which united in its construction as a further addition to the court deposits. All this is apparent from close examination of the remains, but many of the fireplaces, unlike those exposed by previous expeditions, exhibited no trace of a former covering and it may be that they were entirely unroofed. The huts varied somewhat in size and interior arrangement, but they were of the same general type and they served a common purpose.

In their simplest form these associated structures consisted of a roof supported by four uprights and they, in turn, surrounded a circular fireplace. The posts upheld crosspieces and against them, leaning outward toward the ground, was a succession of small poles. It seems most likely that grass and earth covered these sloping timbers, enclosing the room on at least three sides. That portion of the roof lying directly above the firepit was flat and constructed in much the same manner as that of an adobe dwelling, with possible provision for a smoke vent. In ruins of these huts chunks of burned clay, bearing impressions of the several materials which composed the roof, are almost always present upon the fireplace and within the area bordered by the uprights.

These lesser structures were really the living quarters of the ancient people, rooms in which their daily activities were performed. As each family possessed one or more adobe houses—places of protection or for the storage of semi-precious possessions—so, also, did each lay claim to at least one court shelter, an associated structure in which the family cooking was done, where garments and household utensils were prepared and where all those numerous small tasks that occupied the time even of primitive folk were performed. Some such shelters possessed a second fireplace; some a shallow, basin-like

depression near the firepit in which clean sand was kept. Some huts were larger than others; some show longer occupancy; but none is without evidence of its true use, since small implements of bone and stone, charred corn and squash seeds, potsherds, split animal bones, and other camp-fire refuse, may always be found upon the smooth earthen floors and throughout the accumulations which separate the successive levels.

Excavation of the big mound disclosed ruins of still another type, structures not previously noted among the archeological remains of western Utah. Houses of this class possess certain features found, respectively, in the rectangular adobe dwellings and in the adjacent court shelters; they represent, perhaps, attempts to provide the roominess and stability of the former while utilizing methods peculiar to the latter. Rooms 20, 39, 40, 41, etc., are houses of the type under consideration and they are classed as secondary structures, since they apparently have a closer economic relationship to the shelters than to the heavy-walled buildings.

The first of these, although smaller than the others, may be considered typical of all. As discovered, it consisted only of a much-used floor whose outer limits were marked by a series of small post-holes. A rimmed fireplace, 13 inches in diameter and 6 inches deep, had been cut into the floor near the south wall. It would appear that this house had been erected some time subsequent to Kiva V, for example, since several inches of court accumulations, including two ill-defined levels of occupancy, separated the floors of the two structures.[1]

Room 39 was the largest house of this type, and it, in turn, had been built 14 inches above the floor of an earlier structure of the same kind, Room 40. A rimmed fireplace, 38 inches in diameter and 4 inches deep, occupied the middle of the room, and surrounding it, as in the smaller court shelters, were four large roof supports. The walls of this building were constructed of small upright posts, wattled with brush or willows and plastered with mud. More than 30 supports had been utilized in the west wall—the holes they once occupied were only a few inches apart and nearly every one was filled with decayed wood. In part of the east wall, against Room 35, horizontal willows had been bound to the uprights before they were

[1] Four feet four inches above number 20 and at right angles to its long axis was a third-level dwelling, Room 21. Its walls were entirely of adobe, constructed in the manner previously outlined; its floor was hard and smooth and rested directly upon the refuse and loose earth which covered Room 20.

plastered; in another place it was determined with certainty that masses of plastic adobe had been forced between the posts and smoothed over so as to cover them.

Structures of this type, like the smaller shelters, were essentially living quarters or work rooms. Such use is indicated by the central fireplace—fireplaces were not present in any of the rectangular dwellings—and by the small objects found in the débris surrounding it. The two types were designed for similar purposes and, fundamentally, they were alike in construction. Only in form and size did they differ to any marked extent. The central roof of each was supported by four pillars; small poles made up the walls of both. In the smaller shelters these poles slanted downward and outward from crosspieces which rested upon the uprights; in the larger rooms they were set vertically and the wall supported the outer edges of a flat roof, laid in continuation of that directly above the fireplace. Structures of the first type were round or nearly so; those of the second class were quadrilateral.

CEREMONIAL ROOMS

Among the structures concealed by the big mound were three circular rooms and the remains of possibly two others. In form and in their position relative to the adjacent, rectangular dwellings these round rooms may be likened to the ceremonial chambers, or kivas, so inseparably connected with prehistoric Pueblo dwellings throughout the Southwest. They lack some of the structural details of the latter, but their use was so obviously the same that it seems permissible to employ the recognized Hopi term in referring to them. Such application of the word " kiva " has, in fact, already been made[1] by the present writer, in considering circular rooms observed previously at Paragonah and in other sections of western Utah.

In all distinctly Pueblo villages, both ancient and modern, the ceremonial room was the nucleus about which the life of the community revolved; the presence of more than one kiva denoted, merely, that the village was composed of several clans, each having its own unit organization and its own center of social and religious activity. In certain historical Pueblo settlements of New Mexico and Arizona, where Spanish influence was most pronounced, ceremonial rooms lost their original shape when their builders purposely hid them among dwellings of the house cluster, as a means of forestalling priestly opposition. In other existing communities the kiva

[1] American Anthropologist, Vol. 19, No. 1, Jan.–March, 1917.

retained its circular form, remaining somewhat isolated and wholly or partly underground. Pueblo mythology prescribed a subterranean position, in respect to habitations, for purely ceremonial rooms and the Indians of to-day still adhere to tribal custom as far as possible, despite persistent efforts of their conquerors to substitute new religious precepts for the ancient beliefs.

The kivas in the big mound at Paragonah were circular in form; they were entered through a roof opening at a level corresponding to that of the court. This subterranean, or semi-subterranean position, however, appears to have been obtained in a manner somewhat different from that which governed the construction of such rooms in cliff-dwellings and exposed pueblos. In the two latter a location already lower than the houses was frequently chosen or a natural concavity was enlarged and deepened to meet requirements, or dwellings were even built up around the kiva, leaving it in a subjacent position. The circular rooms in the big mound, on the other hand, apparently were excavated from extensive piles of débris—accumulations which permitted the desired subterranean situation and yet left the kiva floors on practically the same level as those of the neighboring secular structures. Whether these piles were wholly artificial or whether they represented merely the usual court deposits could not be determined with certainty by the investigations of 1917. The important fact to be considered is that circular structures have been found in this section of the west and that they were given an underground position in respect to the adobe habitations.

Architecturally, the Paragonah kivas were constructed in a very simple manner. A hole of the desired depth and diameter was excavated from accumulations of earth and camp-fire débris; its walls and floor were then surfaced with mud and allowed to dry. This method appears in sharp contrast to that employed in the adjacent houses where superposed courses were laid with considerable care. In most cliff villages of the Southwest those rooms designed primarily for ceremonial purposes represent the highest local development in masonry, but at Paragonah the contrary is true. The mud plaster was spread directly upon the face of the cut and, from the outside, there is nothing which would suggest the presence of a wall. A roof of the type previously described covered the room and the customary hatchway served as the sole means of entrance. In none of these chambers was anything found which would correspond to the *sipapu,* the fire screen or the wall recesses in prehistoric kivas throughout the San Juan drainage, for example.

Among the circular rooms in the big mound, number 1 is especially noteworthy. As in certain habitations, it illustrates the readiness with which its ancient builders abandoned one building in favor of another or the apparent ease with which they utilized the remains of one structure in erecting a second. Kiva I may be considered as merely the contraction of a larger, similar room whose floor and north wall were retained as part of the later building; it seems a confession on the part of its builders that they lacked the skill necessary to construct successfully so large a structure as that which it replaced. When exposed the walls of the smaller room were practically intact; those of the larger had disappeared except on the north and west sides. The precursor of number 1 had been excavated from the loose court deposits and its walls consisted only of thick coats of mud spread directly upon the ash-bearing earth; the smaller room had been built within the larger, its north wall coinciding with that of the latter and its other sides being formed by the débris thrown upon the floor and within the razed walls of the earlier structure. A rimmed fire-place 26 inches in diameter and 3 inches deep occupied the middle of the floor.[1]

Kivas II and III are really counterparts of number I, although differing somewhat in size. The third of these, unfortunately mutilated during the removal of the south end of the mound, had also undergone repairs, a second floor having been laid 2 inches above the first. The room is still further unique in possessing an extra fireplace, adjoining and but slightly smaller than the usual central hearth. Against the southwest wall was a posthole which held a support for one of the heavy roof beams, a feature also noted in kivas exposed during the expeditions of 1915 and 1916.

The curved wall fragments of possibly two additional kivas were observed, respectively, within Room 35 and in the open court east of Rooms 8 to 12. The first of these measured only a few feet in length; its floor, although broken and so near the surface as to render its exposure difficult, was traced beyond the razed east wall of Room 35. This room was circular in form and there seems but little doubt that it was used chiefly for ceremonial purposes.[2] Greater uncer-

[1] In the court accumulations between Kiva I and Rooms 8 and 32 several levels of occupancy, from 2 to 10 inches in thickness, were noted. Each of these showed fireplaces and the remains of shelters associated with the neighboring rectangular habitations, but the ground plan does not presume to delineate all of those discovered.

[2] The necklace of bone pendants and "gaming counters" noted on page 16 was found on the floor of this room.

tainty exists regarding the other room, which has been marked Kiva V. Its floor lay in that portion of the mound where superposed levels of occupancy were most numerous, and it may be that the room was no more than an enlarged shelter. Fragments of curved adobe walls remained on the eastern side and these, if continued, would have circled a central fireplace about which four large pillars formerly stood. It is the presence of these surrounding posts that suggests the possibility of this having been one of the numerous associated structures, but kivas with roofs supported by uprights were noted, also, during preceding expeditions and in so large a room pillars would have been absolutely necessary. Curved adobe walls, on the other hand, have not yet been observed among the remains of purely court shelters.

MINOR ANTIQUITIES

In reviewing the minor antiquities exposed during the excavation of the "big mound" the observer will, first of all, be attracted by the preponderance of bone objects. Bone implements and ornaments of many shapes and sizes, and in various degrees of completion, were found in unexpected numbers; in addition, there were large quantities of mere refuse—bones split to facilitate the extraction of marrow, charred bones, and those apparently tossed carelessly to one side. Among this mass of worked and unworked material there may be recognized skeletal fragments of such animals as the deer, antelope, mountain sheep, bear, and various smaller mammals. There are also a few fragments of heavy antler which appear to be elk and several pieces of large, worked bone that have been tentatively identified as those of the buffalo. All of these, taken together, indicate that the ancient house builders were persistent hunters and that the animals killed not only contributed largely to their food supply, but formed, also, the chief source of one of the materials most essential to the economic pursuits of the community.

Awls are especially numerous and vary in size from the small, sharpened metapodial of the deer to those cut from the full length of the canon bone. Most of them are merely ground and sharpened fragments, but several exhibit a high degree of specialization and are really pleasing examples of aboriginal art. A few were perforated at the butt end for the attachment of a cord and still others, as in plate 11, were decorated with incised lines. Some of the awls are long and slender, like needles; others are heavy, blunt, and

frequently chipped at the end as though employed as punches in flaking arrow points, etc. But all of them, crude and finely worked together, were utilized in the daily activities of their owners, in weaving baskets, in making skin garments, and in numerous lesser tasks for which they were not, perhaps, especially intended.

Closely allied to the bone awls is rather an extensive group of implements shaped from antler. These include chiefly punches and flaking implements, but there is, also, a remarkable collection of wedges, three of which are figured in plate 12. Among the antler fragments, as with the bones, there are specimens that accurately illustrate the manner in which they were prepared for use—specimens which include selected though unworked tynes, those partially or completely sawed with flakes of flint and cut pieces that show various stages in the grinding process by which the objects were brought to completion.

Next to the awls, numerically, is a large series of more or less carefully shaped objects, some of which are shown in plate 13. Most, perhaps all, of these were employed as dice or counters in various games and yet some of them were unquestionably adaptable to other purposes. The series is truly noteworthy, both in point of number and in the workmanship of many of the specimens. These arrange themselves naturally into groups, according to the character of the finished object—groups which range from the rudely chipped counter to those neatly polished, perforated, and ornamented by drilled dots or incised lines. A large percentage of these, crude and highly worked alike, bear traces of red paint on the under or concave side and it may be that each one was so marked when in use. That all of these, especially those which are perforated, were not employed exclusively in games is indicated by the recovery of 10 charred "counters" together with 14 bone pendants—the whole probably forming a necklace—from the ashes of a fireplace in Kiva IV.

Pendants and broken counters reworked to form like ornaments, beads of various sizes, small gaming disks or dice and even finger rings are among the bone objects collected. The latter, especially, will bear brief consideration, since the specimens recovered illustrate each stage in ring manufacture. A section of predetermined width was sawed from a large bone, as indicated in plate 11; this piece, in turn, was ground down and polished by rubbing on sandstone and perhaps later carved or incised with lines. The hollow character

of certain mammal bones probably suggested this use, and primitive delight in personal adornment quickly led to the adoption of the new ornament. Complete specimens were fewer in number than the fragments recovered, but all are highly interesting and most of them speak well for the artistic ability of their makers.

Objects of bone collected by the 1917 expedition were important both in quantity and in quality of workmanship. The stone artifacts, on the other hand, although numerous, embraced but few types and these exhibit no marked deviation from similar imple-

FIG. 1.

ments, widely distributed throughout the Southwest. As might be expected, hammer stones and mullers predominate, but there are also large numbers of rubbing and polishing stones, discoidal jar covers, gaming balls,[1] etc.

Grooved axes and mauls seem to have been wholly unknown to the inhabitants of the adobe dwellings. After three summers' work among the ruins of western Utah the writer has found but one implement, figure 1, which even approaches an ax in form and this is a crude basalt hammer, notched for hafting, and probably made

[1] Small stone balls, usually encrusted with a softer material, were employed by various southwestern tribes in games for both adults and children. The recent expedition collected 75 of these and, in addition, two specimens of adobe. To one of the latter was still attached a fragment of its original clay covering.

from a fragment of a broken muller. The absence of these common North American implements is, in itself, significant; especially so, since suitable stone was not entirely lacking. It means either that the aborigines had not yet discovered the feasibility of stone axes—which is almost unbelievable, considering their advancement in other lines—or that they were still content to use other weapons and to employ fire in felling the larger timbers utilized in the construction of their dwellings and associated structures.

Most of the metates, or stones on which corn, etc., was crushed, are of a type peculiar to western Utah. They consist of fairly large basaltic boulders and are generally but little worked, excepting the upper surface. The exceptional feature of these metates is the small, secondary area adjoining the grinding surface and at that end of the stone which would have been elevated while in use. It is usually, though not always, concave, but whether it was designed as a rest for the muller or intended primarily as a container for ground meal is still problematical. It would have answered either purpose, although not absolutely essential to the efficient use of the metate. The small basin does not customarily appear on stone mills found elsewhere.[1]

Traces of red paint on both metates and mullers illustrate the readiness with which primitive man employed his various utensils in the task at hand. Red ochre was collected along the foothills, brought to the village and pulverized for use in bodily adornment and the ornamentation of pottery, etc. The frequency with which paint-covered mullers are found indicates that the quantity of natural pigment employed by the ancient people of Paragonah was not inconsiderable. It is not apparent that they employed special mortars and pestles in the preparation of paints as was done at Zuñi and elsewhere.

The pottery exposed by the expedition of 1917 is much the same as that found during the excavations of the two preceding years. A majority of the shards recovered are of plain ware; corrugated vessels were evidently less common than in ruins farther north. These fragments, however, taken with those which bear traces of ornamentation, are sufficient to indicate the development of the ceramic art among these house builders and to establish a cultural affinity between them and the ancient people south and east of the

[1] The writer's attention has been called to a similar metate discovered on the outskirts of Moab in Grand County, Utah, by Dr. A. V. Kidder of Harvard University.

Rio Colorado. Decorated jars and ollas were obviously rare, but bowls carrying the customary black decorations over a gray interior wash were plentiful. On these latter are figured many of the geometric patterns common to the northern part of the prehistoric Pueblo area; only one shard has been noted which carries a representation of an animal. However instructive a comparison of the earthenware vessels from the two regions might be it again seems advisable merely to affirm the similarity in design and leave for a future paper detailed consideration of the western Utah pottery.

An examination of these Paragonah fragments discloses one peculiarity of ornamentation which is too often repeated to suggest mere accident. This is the interlineal use of red paint, superficially applied. The black decorations were painted directly upon the kaolin wash and were permanently fixed when the specimen was fired. Some of these, however, especially bowls with encircling bands, were further ornamented with red ochre and this almost without exception was drawn between the black lines some time after the vessel had been removed from the kiln. The red paint, not being permanent, is readily removed by rubbing, but its decorative effect remains unquestioned. Plain-ware bowls and jars and even coiled ollas were sometimes covered on the outside with a thin coat of this same pigment, producing results which, in general appearance, approach the unpainted red ware of the Little Colorado drainage. Judging solely from the shards collected, earthenware vessels decorated with red before firing were extremely rare in the Paragonah region.

Besides the usual objects of bone, stone, and pottery, a number of less common artifacts were recovered from the big mound. Perhaps the most interesting of these is a tubular stone pipe, figured in plate 15. The original, now in the University of Utah Museum, is of agalmatolite, or possibly serpentine. It is of the well-known California type and undoubtedly reached the Parowan Valley through inter-tribal commerce.[1] The typical Utah pipe—if a type can be determined from incomplete investigations—is of clay and varies between numbers 303177 and 303179, plate 15. Short tubular pipes with flaring lips have been found in widely separated localities; clay

[1] That materials and artifacts prized by primitive peoples were frequently transported almost incredible distances is a fact well known to anthropologists. Several dozen beads made from Pacific coast shells (*Olivella biplicata*, Sby. and *Olivella dama*, Mawe), were found in the "big mound" and indicate that the difficulties of a foot journey across the Nevada and California deserts were not insurmountable.

pipes[1] with bowls inclined upward at the end of the stem, or lying wholly within it, are not uncommon and these, too, are widely distributed throughout the region of the adobe houses. Stone pipes of this same general type, but much heavier than those of clay have been found in other western Utah mounds, although none were discovered by the recent expedition.

Among the lesser antiquities recovered are certain seeds and pieces of basketry—perishable articles whose charred condition is alone responsible for the their present degree of preservation. The first of these includes grass and squash seeds, corn, beans, and piñon nuts—foodstuffs which indicate that the old house builders knew something of agriculture and did not rely wholly upon the skill of their hunters. The basketry, one fragment of which is illustrated in plate 12, is of the coiled variety so common among the ancient cliff-dwellers and represents a high quality of workmanship. Baskets were unquestionably in constant use by the primitive folk of Parowan Valley and far more numerous than their occasional remains would lead one to believe.[2]

Something has been said above of the use as paint of clay stained with oxide of iron. Pieces of yellow ochre were also found, but these were undoubtedly employed chiefly for bodily adornment. So far as known, potsherds bearing indications of yellow decoration have not yet been discovered in western Utah mounds. Small masses of kaolin are occasionally recovered from these ruins—masses that furnished the whitish coat with which the vessels were surfaced, previous to the application of decorative designs. Some of them, however, are so nicely shaped and of such definite form (pl. 12, a) as to suggest their possible use in certain kiva ceremonies.[3] A con-

[1] The small effigy pipe, number 301976, plate 15, is the only one of its kind known to have been found in a Utah mound. The original, now in the University of Utah Museum, is of clay and probably represents a ground squirrel; its stem had been broken one-half inch from the bowl, but was subsequently ground down for continued use.

[2] Rumor has it that pieces of charred cotton cloth have been found during previous excavations at Paragonah, but no traces of such fabric were discovered by the 1917 party.

[3] A story often repeated at Paragonah relates that the walls in one of the adobe dwellings previously exposed were painted white and, over this, figures in red, green, and yellow had been drawn. The excavation of many similar ruins, both at Paragonah and elsewhere, has failed to disclose any trace of like ornamentation, although walls are frequently observed whose faces are covered with a thin coat of alkaline salts, deposited by the network of rootlets which follow down the hard wall surface and tend to separate it from the softer accumulations of débris and wind-blown earth. In the opinion of the writer,

siderable vein of this material is said to exist in the Escalante Desert, northwest of Rush Lake and about 20 miles west of Paragonah.

Two or three small masses of sulphur were also found among the house remains. None of these, however, bears any mark which would suggest that the mineral had been intended for, or put to, a definite use. It would appear most likely that the original collector had been attracted merely by the color of the stone and carried it to the village under the assumption that it could be ground into paint.

A few fragments of ore-bearing rock were recovered at the same time. These were utilized solely as hammer-stones and are not, as might be inferred, evidence that the ancient house builders possessed knowledge of smelting processes. Implements and ornaments of metal are entirely unknown among the Utah ruins—persistent local contentions to the contrary—and they have never been discovered in pre-Spanish villages in any other section of the Southwest, excepting, of course, those few southern Arizona and New Mexico localities that had established inter-tribal communication with the peoples of central Mexico. The highly colored stories so widely circulated throughout Utah regarding the discovery of gold, silver, and iron artifacts in purely prehistoric ruins are deliberate fabrications whose chief purpose seems to be the willful deception of the most credulous. Tales of this sort have frequently acted as a spur to those seeking supposed fabulous riches and are directly responsible for the wanton destruction of many aboriginal remains whose historical value cannot be over estimated.

SUMMARY

Certainly the chief result of the recent Smithsonian Institution-University of Utah expedition was the successful exposure of some 40 odd houses and numerous associated structures, comprising the greater part of an extensive prehistoric village. These were of entirely distinct types, grouped to form a single compact community; their apparently studied arrangement and the obvious relationship between them and the nearby, circular rooms is evidence that definite social and religious principles governed the daily life of their occupants. The more permanent dwellings were of adobe, built up usually in courses and smoothed or plastered on the inside; the secondary buildings may be described as brush shelters—the living quarters of the villagers—in which were performed most of their

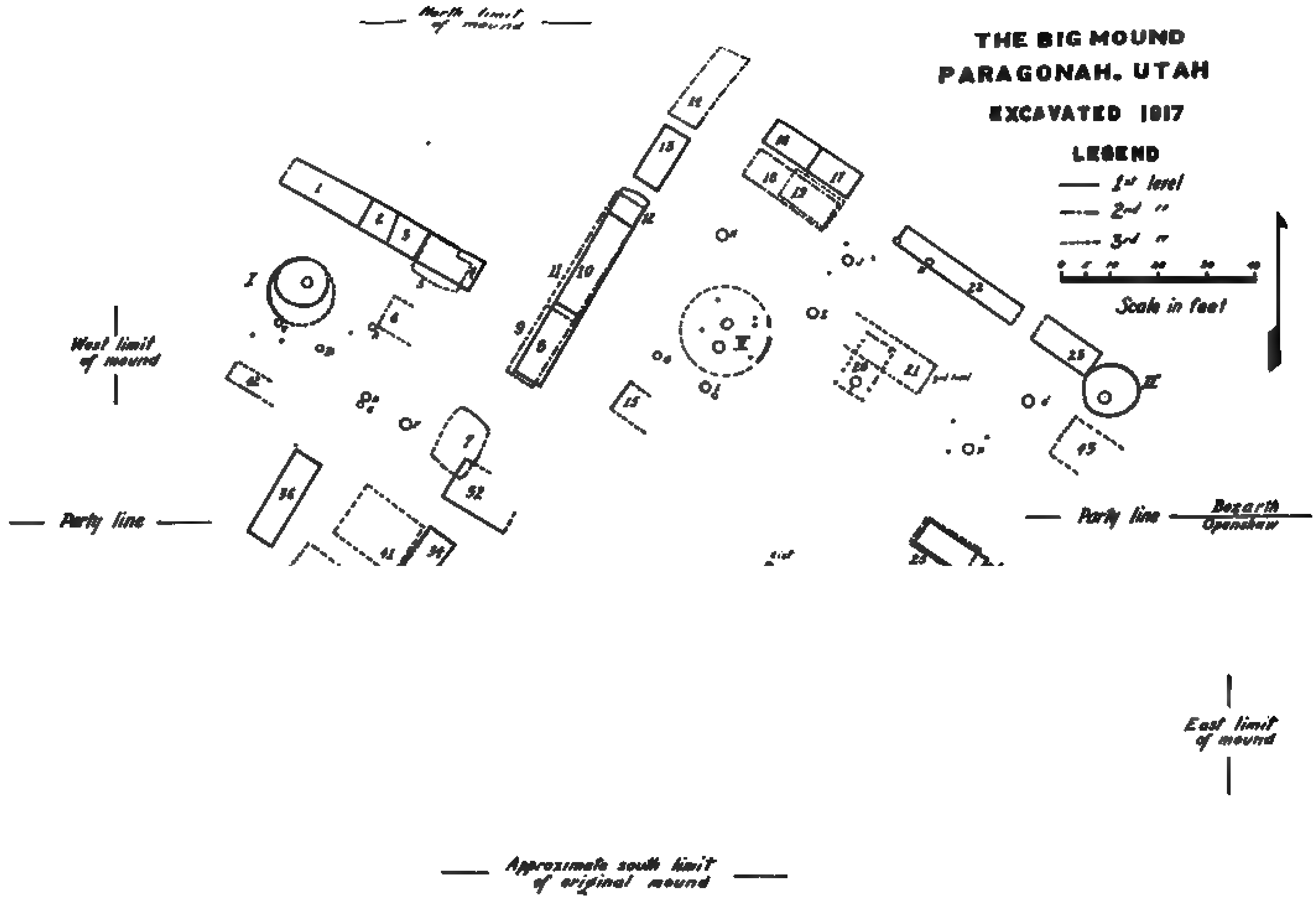
these salty deposits were mistaken for "whitewash"; the "paintings" may be wholly or in part the product of the imagination.

domestic activities. The shelters seemingly were erected without serious consideration of their possible interference with the general plan of the village; they were easily constructed and the site chosen for each appears to have been the least obstructed space nearest the home of the prospective builders. Huts of this type, together with the adobe houses, acted as natural barriers that caught and held the wind-blown sand and earth as it swept across the treeless foothills and settled in and among the dwellings, adding materially to the size of the mound. Not all of the exposed dwellings were inhabited simultaneously and it is highly probable that many decades elapsed between the occupation and abandonment of the site.

Ceremonial chambers adjacent to the secular structures suggest that at least three clans had united in the establishment of the village. In form and their obvious connection with the neighboring habitations these circular rooms resemble the kivas in cliff-dwellings and historical Pueblo villages. Although certain structural details commonly identified with the latter are absent in the Paragonah kivas, but little doubt remains that they served similar purposes and exerted equally important influences upon their respective builders.

Large numbers of artifacts were recovered from the refuse heaps which filled the open spaces between the houses. Most of these are of bone and stone, but charred fragments of more perishable materials were also found, and all of them, taken together, indicate that the ancient artisans possessed considerable ingenuity and attained creditable results with their crude implements. Among the objects collected are many shards of earthenware vessels decorated with geometric figures of a type common to prehistoric communities south and east of the Rio Colorado. Inasmuch as decorative motives did not change readily among the ancient house builders of the Southwest this similarity in pottery design is noteworthy.

Not only the character and ornamentation of certain lesser antiquities, but also the structural peculiarities of the rectangular dwellings and their general relationship to each other confirm the opinion that a marked cultural affinity existed between the ancient people of Parowan Valley and those inhabiting the semi-arid regions east of Navaho Mountain. Just how extensive and far-reaching this may be can be determined only by additional investigations—researches that shall have for their prime motive the tracing of the ancient culture so characteristic of western Utah. Once these limits are ascertained the problem of the Utah mounds will have been solved and the builders of the adobe dwellings will have found their rightful place in the story of our prehistoric Southwest.


THE BIG MOUND
PARAGONAH, UTAH
EXCAVATED 1917
LEGEND
1st level
2nd "
3rd "
Scale in feet
North limit of mound
West limit of mound
East limit of mound
Party line
Party line Bozarth Openshaw
Approximate south limit of original mound

Trenching in search of rooms on the northwest quarter of the mound. View from the north.

Excavated northwest quarter of the big mound with Room 14 in the foreground. Compare view above.

Decayed remains of large upright cedar posts which formed the west wall of Room 43.

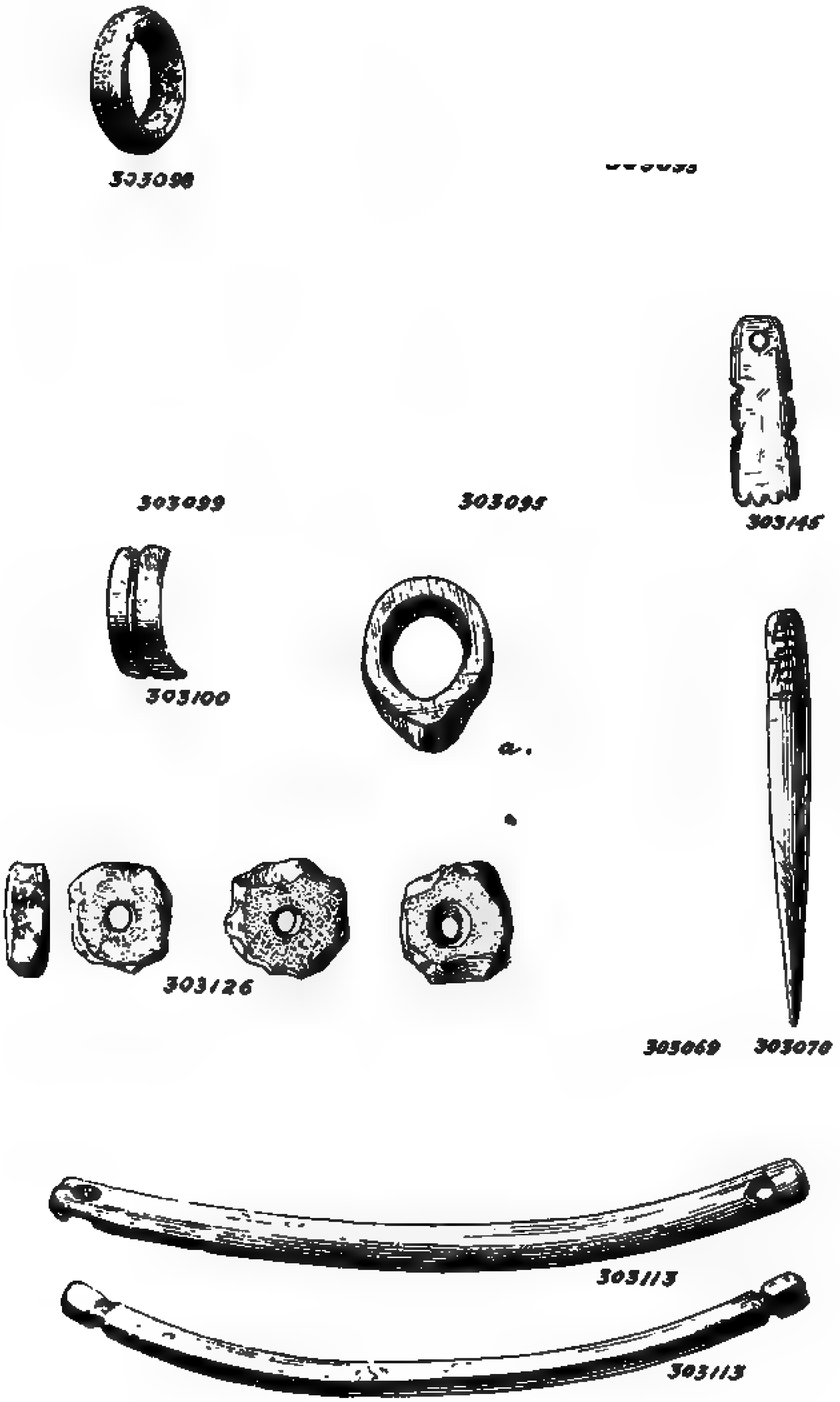
Superposed adobe dwellings, 16-19, with the floors of Rooms 18 and 19 plainly visible. The men are at work in the central court, near Kiva V.

Kiva III from the southwest; the two central fireplaces appear indistinctly in the foreground; numerous squirrel burrows pierce the walls.

Looking down into Kiva II from above Fireplace O', with Room 23 showing at the left.

Looking into Kiva I from a point near Fireplace C, but within the standing south wall of the larger ceremonial chamber first constructed. Part of the latter appears at the left.

Rounded masses of adobe wall material under the floor of Room 19. It will be noted that these are not all of the same shape or thickness.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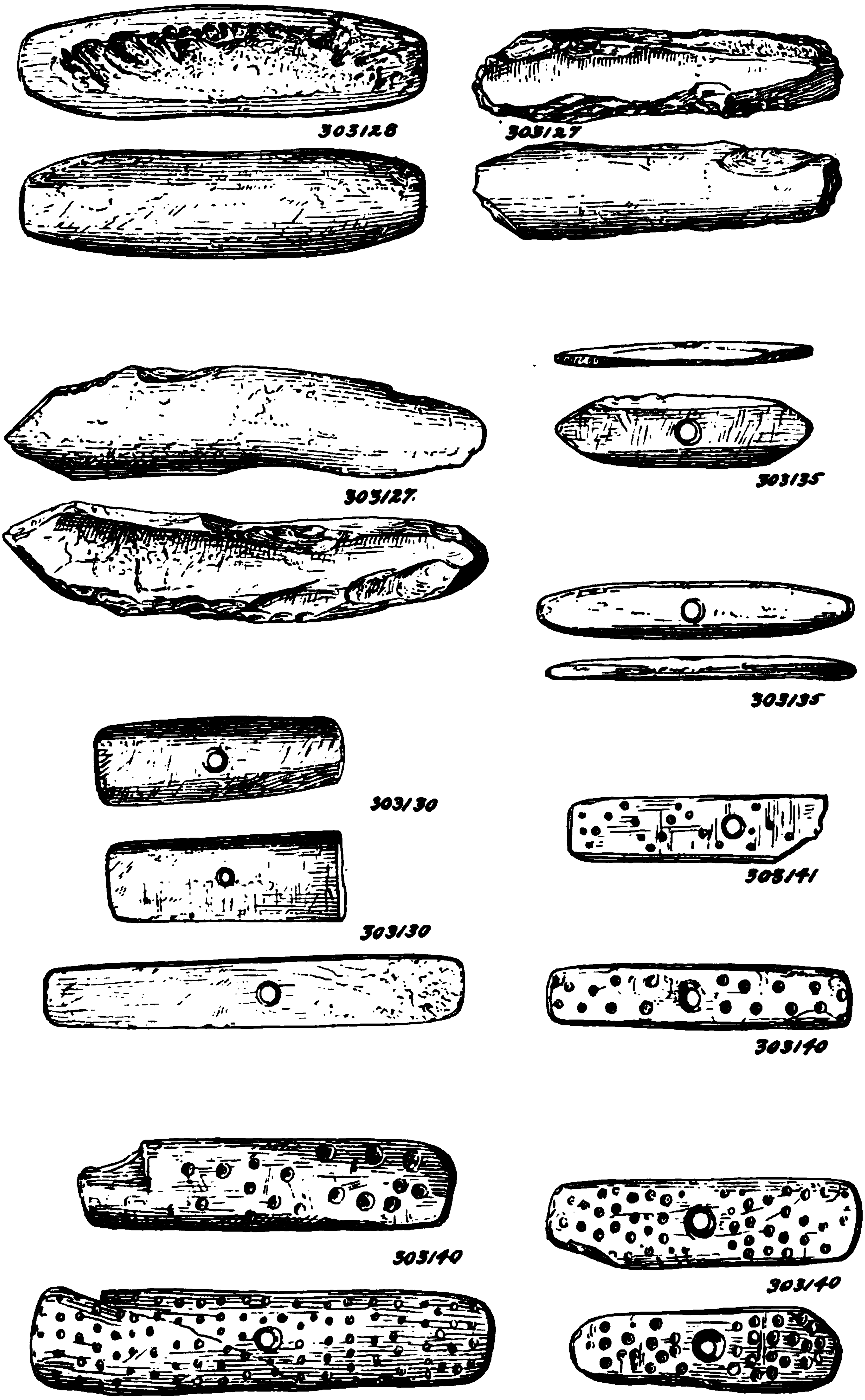
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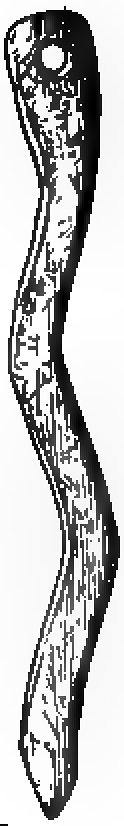

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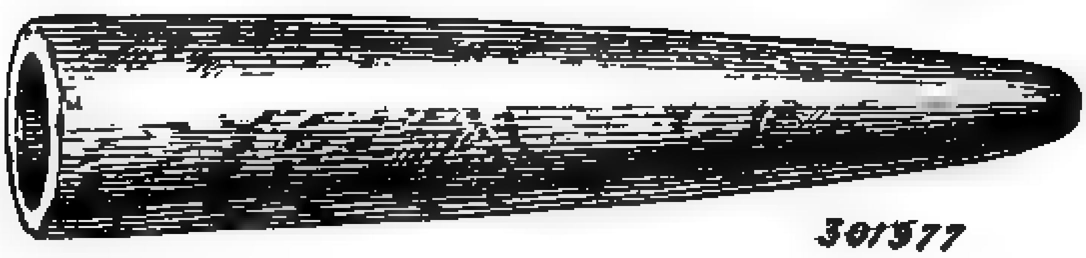

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TEMPERATURE VARIATIONS IN THE NORTH ATLANTIC OCEAN AND IN THE ATMOSPHERE

INTRODUCTORY STUDIES ON THE CAUSE OF CLIMATOLOGICAL VARIATIONS

(With Forty-eight Plates)

BY
BJÖRN HELLAND-HANSEN AND FRIDTJOF NANSEN

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CONTENTS

PREFACE

In different oceanographic investigations during recent years we have been confronted by a series of important questions relating to the reciprocal action between the sea and the atmosphere. We have formed a plan of examining these relations more closely in the hope that we may thereby make some contribution to the understanding of climatological variations.

In the present work we have examined some of the purely oceanographic relations which are important in the problem and we have also made a series of investigations on the climatological variations themselves. These studies, however, form only the first and introductory part of a greater investigation, and we do not now endeavor to give a final solution of the problem. In a later continuation of the investigation we hope to penetrate deeper into the question, which indeed for its thorough discussion demands such an enormous mass of material that we have not as yet succeeded in collecting it.

In our endeavor to gather information relating to the Atlantic Ocean we have been so fortunate as to find in Herr Adolf H. Schröer an interested and helpful colleague. He has repeatedly made journeys to Hamburg in order personally to promote the arrangement of the great quantity of observational material which we have obtained at the Deutschen Seewarte there, as a starting point for our investigation. We offer to him our best thanks for this valuable help which he has given us.

We also give our warmest thanks to the officials of the Deutschen Seewarte for the willingness with which they have put their great collection of ships' log-books at our disposal as well as for the great kindness with which they have facilitated the extraction of data from them.

THE AUTHORS.

June, 1917.

TEMPERATURE VARIATIONS IN THE NORTH ATLANTIC OCEAN AND IN THE ATMOSPHERE [1]

By Björn Helland-Hansen and Fridtjof Nansen

I. THE AIM OF THE INVESTIGATION. THE ASSEMBLY OF THE OBSERVATIONAL MATERIAL

In 1909 we found that the water-masses in the Atlantic currents of the Norwegian sea (with a salinity of more than 35 parts per thousand) experience great temperature variations from year to year. These variations, according to our view, may find their explanation either by different proportions of mixture between the water masses of the Atlantic Ocean current which passes through the Faroe-Shetland Channel (and also northward of the Faroe Islands) and those of the Icelandic-Arctic current—or, on the other hand, by variations in the water-masses in the Atlantic Ocean currents themselves before their entrance into the Norwegian sea.

In order to decide this question, we held it desirable to study the possible variations from year to year in the temperature of the North Atlantic and their causes. Unfortunately there was not available enough observational material for a long series of years on the temperatures of the deeper water layers of the Atlantic Ocean. It was moreover questionable if the numerous surface observations would answer for our purpose.

As has been shown by several investigators, the vertical convection reaches in the winter in the North Atlantic Ocean to very great depths (see Neilsen, 1907, p. 10, Nansen 1913, p. 18, etc.). Somewhat similar results were found by Helland-Hansen in the Norwegian sea in a February expedition in the year 1903. Although apparently the vertical convection there did not reach to so great a depth as in the North Atlantic Ocean, yet he found equal temperatures and equal salt contents reaching very considerable depths below the surface. The isotherms and also the lines of equal salt contents in the sections show a very steep almost vertical position, which is partly to be explained because the vertical convection equalizes the differences (see Helland-Hansen and Nansen 1909,

[1] Translated from Videnskapsselskapets Skrifter. I. Mat.-Naturv. Klasse. 1916. No. 9, with additions by the authors and by Dr. C. G. Abbot, Smithsonian Institution, Washington, U. S. A.

p. 229) and partly by the lateral oscillation in summer and winter (compare 1909, p. 227).

It was therefore to be expected that during the colder parts of the winter and towards the end of it the surface temperature could be used as an indicator of the heat condition of the ocean masses to relatively great depths. Accordingly one would expect that the yearly variations of the surface temperature of the sea during the coldest part of the winter would correspond to the variations of the winter temperature of the water layers lying underneath. If that is in fact so, a study of the surface temperature of the sea during the winter should give valuable hints on the variations of the temperature of the water-masses which are carried along by the various ocean currents.

In our investigations of the surface temperatures of the Atlantic Ocean it was natural that our attention should be drawn to the very large collection of ships' log-books at the Deutschen Seewarte. Our colleague, Herr Adolf H. Schröer undertook therefore the task of going to Hamburg in order to make necessary abstracts from these log-books. In this work he received the kind cooperation of the direction and staff of the observatory, so that he was able to attack the matter in the best way.

In the choice of the region of the sea to be investigated the observational material gave decisive indications. The choice fell upon the much travelled ship course between the English Channel and New York (see fig. 1 and pl. 15). The observations of the air and surface temperatures were collected for the period of years 1898 to 1910 according to one degree fields. In these tables all the observations which could be found were entered, principally being those of steamships, but including those of sailing vessels.

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west longitude and from thirty-seven degrees to forty-five degrees north latitude (see fig. 1 and pl. 15).

Herr Adolf Schröer has given us a statement on the first collection of observational material (March 15 to April 13). From this statement we give the following figures, in which an air temperature and the corresponding water temperature rank as one observation:

Year	1898	1899	1900	1901	1902	1903	
Observations	782	878	817	825	1174	868	
Year	1904	1905	1906	1907	1908	1909	1910
Observations	1215	2229	2293	2382	2167	2663	2122

—altogether 20,415 observations.

It is clear that the numbers of the observations made before and after 1905 are quite different. The reason for this is that prior to 1904 there were generally eight o'clock morning and evening observations made, whereas after 1904 we used exclusively journals in which the observations were made at the end of each four-hour watch.

The observational material at hand from the ships' log-books is very unequal. Formerly the observatory was satisfied with results to 1° or 0.5° but later the results were demanded to 0.1° accuracy. According to many reports, the observations from the meteorological journals were made on numerous ships, not by the officers, but by the seamen. That in these circumstances the estimation of tenths of a degree did not add to the accuracy is hardly doubtful. The thermometers employed were very unequal. In some journals there are no indications as to the accuracy of the instruments employed. In those thermometers for which corrections are given, we find them mostly only at relatively great intervals, for example at 0° and at 20°. For many thermometers the corrections were altogether too large, even in excess of 1°, hence one would draw the conclusion that the material is quite untrustworthy. If one should reject all the bad thermometers, however, he would have to throw away from thirty to fifty per cent of the material. We have therefore only rejected those journals for which thermometers were used which gave between 0° and 20° corrections larger than 0.5°. For all thermometers for which the reading was only to 1° or to 0.5° in accuracy the small corrections were disregarded. Only for the readings supposed to be of 0.1° accuracy were the corrections employed.

II. THE OBSERVATIONAL MATERIAL

Since the number of the observations in the 1° fields of the different decades is often somewhat small, we found it desirable to combine the results of the single observations in fields of 1° latitude 2° longitude which we may call 2° fields.

For each of these 2° fields we have taken the mean temperature in the two decade groups February 3 to March 4 and March 15 to April 13, respectively. As we shall see in Chapter III, the actual differences in the mean temperatures over the whole region for separate decades are not large. But since the number of observations in single decades are often very small, better mean values may be obtained for the two decade groups by taking the simple mean of all the assembled observations in each of them, rather than to treat the separate decades independently. We have therefore always

FIGURE 1. The 2° fields of the observations (cross-hatched) along the route Channel to New York and the more southerly 10° fields between 10° and 40° of west longitude. The circles with the numbers 1 to 12 give J. Petersen's stations (1° fields), and the cross-hatched 1° fields with the numbers L1 to L3 give Liepe's stations.

taken the group mean as the mean of all the observations without reference to their division between different decades. The values of the surface temperature so obtained will be found in plates 1 to 14, where also is given the number of observations for each field.

In many fields the observational material is so scanty that even the values for the decade groups are doubtful. For these fields the calculations of mean temperatures for the single decades are omitted. However, there is a series of 2° fields along the route Channel-New York, where the number of the observations is sufficient for this purpose. These fields are shown by cross hatching in figure 1 and also plate 15. In them, we have therefore given the mean values for the single decades, as well as the mean values of all

the observations for the two three-decade intervals. The observational material for these fields is on the whole very full, though the number of observations in each decade group in the weakest cases is less than 20. But in general and for the later years after 1904, the numbers exceed 40 or even 50 in the decade groups.

In the southern region (between 10° and 40° west longitude and 37° and 45° north latitude) the observations, as the plates 1 to 14 show, are so scattered that the mean temperatures which are determined for two-degree fields are very untrustworthy. For this region, in which the local temperature differences are comparatively small, we have therefore reduced the observations in larger fields of 2° latitude and 10° longitude. These 10° longitude fields are indicated in figure 1 and also in plate 15 by cross hatching.

With the help of the mean values of the temperature for the decades and decade groups of each year, we have computed the normal temperatures of the surface and of the air for each of the chosen fields. There were in all sixty fields, forty-eight northerly 2° fields, and twelve southerly 10° fields. In this computation we used only the values for the eleven years from 1900 to 1910 inclusive, because the observational material for the two first years, 1898 and 1899, is not satisfactory. Finally the anomalies for the single decade and decade groups for each year were computed. These anomalies may be found in tables 1W, 3W, 6L and 8L, where also the normal temperatures for the water and the air are given.

Concerning the accuracy of the temperature observations in our material one must admit that this is only moderate. This remark holds for the temperatures of the ocean surface but more particularly for those of the air. The readings, including those of the water temperatures, are often given in whole degrees, frequently in half degrees, and even the accuracy of the numbers themselves is often doubtful. At single stations, the temperatures given are sometimes impossible, as for example, water temperatures of -3° C. or even -4° C.! An explanation of these errors is hard to give. It appears as if at many stations the surface and air temperatures were interchanged. We have cast out the obviously false observations. In tables 1W, 3W, 6L and 8L, the computed mean values in such cases are indicated by bold-faced type.

In single cases where observations have been wholly lacking or where the computed mean value on account of too small a number of observations seemed improbable, we have introduced a new value by interpolation. In forming this value, the temperature relation

of the decade in question or of the group of three decades to temperatures of neighboring fields on both sides has been examined. Also the yearly change in these neighboring fields. The values built up in this manner are distinguished by brackets in tables 1W, 3W, 6L and 8L.

In spite of the unsatisfactoriness of the observations, both as to their number and as to their accuracy, it appears that the values found for the surface temperature fall in good harmony.

In the isopleth diagrams (on the right in pls. 17-41) which show the distribution of the plus and the minus anomalies both in time and in region from decade to decade and from field to field, we see that in almost all cases a certain connection or system is found in the distribution of the anomalies. It infrequently appears that a minus anomaly is to be found between plus anomalies or vice versa. In general the march of the changes in the signs of the anomalies and in their magnitudes goes gradually along from field to field and from decade to decade. This seems to show that our mean values correspond well with the actual truth even for the single decades. Obviously this is probably, in a yet higher degree, true with the mean of all observations for two groups of three decades each. This inference is easily confirmed by the graphical representation of the values.

The curves for the single fields in the eastern part of our region up to about 50° west longitude agree in all essential particulars astonishingly well with one another, and change gradually from field to field in a way which shows that they must correspond well with the actual temperature relations, and cannot be changing in a haphazard way (see figs. 16-19). That the agreement is less striking in the western part depends upon conditions of which we shall speak later.

Our observational material on the air temperatures is less perfect than that on the surface temperatures, for three reasons: First, the single determinations are ordinarily less satisfactory; second, the daily amplitude, which we cannot take account of, is much greater than that in the water temperature and accordingly a limited number of air observations must give less satisfactory values than an equal number in the water. Besides, in several cases a somewhat smaller number of air observations is available for the computation of a mean temperature value, since the surface temperatures are not always accompanied by a determination of the air temperature. On the other hand the observations were not infrequently

air temperatures unaccompanied by the corresponding water surface temperatures, but such observations we have rejected.

In spite of all this, it appears from our graphical representations that the values found for the air temperature must on the whole be fairly satisfactory in the eastern part of the region even for the single 2° fields. However, in order to save space we have not given curves of air temperature in the single 2° fields corresponding to those of the surface temperatures given in figures 16-19. On the other hand, we have given in figures 44 and 46 a summary of the surface temperature minus the air temperature for the single fields. These curves show such good corresponding agreement and such completely concordant gradual variation from field to field that they show both for the air temperature and for the water temperatures that the real facts are on the whole determined.

In order where possible to show a comparison of the values of the variations which we have found in the North Atlantic Ocean south of 50° north latitude with the temperature variations in the northerly regions of this ocean, we have employed the monthly surface temperatures published by the Danish Meteorological Institute for the ocean north of 50° (see "Nautisk-Meteorologisk Aarbog" Copenhagen Nautical Meteorological Annual published by the Danish Meteorological Institute).

Along the Danish steamship routes north of Scotland to New York, to Iceland and to Greenland, these charts give the mean semimonthly temperatures for each single degree field for the interval 1898 to 1910. The values correspond, one to the first half of each month, and the other to the second half. For the years after 1911 there are simply the mean temperatures for the whole month, but there is given a small figure which shows on how many observations each of these values is founded. Unfortunately the number of the observations in each month for each of these fields is very small. This holds particularly for the months February–April, which we have investigated, when the number of the observations for each field is very often only from one to four or five. The temperatures for the single fields cannot therefore be regarded as of high accuracy.

In order to reduce the accidental errors as much as possible, we have combined two by two the 1° fields together, so as to make fields of 2° in longitude and 1° in latitude. With the fields thus obtained we have the monthly mean temperatures for the interval from 1898 to 1910, including the month of February as well as

the second half of March and the first half of April, that is, for the time interval from March 16 to April 15, which corresponds closely with our second decade group, March 13 to April 13. We computed also the general mean value of the mean temperatures for each 2° field for February and for March-April for the years 1900 to 1910 in the same way as we used the observational material of more southern regions, and we used the mean values so found as the normals for each field. From this we obtained the anomaly for each field for February and for the time interval from March 16 to April 15 for each year.

The anomalies so found unfortunately could not be regarded as very satisfactory, for even in the 2° fields they rested on too few observations. By combining the mean of the anomalies for all the 2° fields within each 10° longitude interval together, we may suppose that values which will correspond better with the truth would be obtained, since the accidental errors will thereby, at least in a certain degree, be eliminated.

In this way, the mean anomalies for 10° fields of longitude along the route north of Scotland-New York were obtained lying within the zones between 40° and 30° west longitude, 20° and 10° west longitude and 10° and 0° west longitude. For these 10° longitude fields, we have used only those 2° longitude fields in which the observations in the most years were most complete. The fields may on this account be a little different for February and for the interval March-April. They are, along with the corresponding temperature values given in table 4W and in plate 15 (21-24) where they are indicated by cross-hatching.

Along the route from the Faroe Islands to Iceland we have in a similar way determined the temperature anomalies for large fields for which sufficiently many observations were available. The fields are shown on plate 15 (25-27) by cross-hatching, and in table 4W indicated over the temperature values. Since the observational material in March-April was considerably richer, more fields could be employed in this interval than in the month of February. In March-April also the voyages to Greenland were already begun, and we could give the temperature anomalies for some fields along this route, also between 60° and 61° north latitude and westward from 20° to 28° west longitude (see tables 4W and pl. 15, 28).

Finally, there were also in the fields between 0° and 3° west longitude and between 56° and 57° north latitude, on the west coast of Scotland so many observations that we also determined tempera-

ture anomalies for this field (see table 4W and pl. 15, 29). These values could hardly be regarded with very great confidence on account of the small number of available observations.

FIGURE 2. The surface currents of the Atlantic Ocean in the northern winter according to Schott: Geography of the Atlantic Ocean. Full drawn lines indicate warm currents, the dotted lines cold or cool currents, dotted regions are regions of prevailing side streaming, circles indicate regions of prevailing slack water, crosses indicate regions with up-flowing cold water from the depths. Curve I gives the average boundary of the drifting ice and of the icebergs, curve II the outside boundary of icebergs of extraordinarily cold years, curve III the region of the prevailing presence of Gulf seaweed.

III. SURVEY OF THE REGION INVESTIGATED

The greater part of our region of investigation is ruled by the great oceanographic phenomenon called the Gulf Stream. The principal features of the surface relations of the ocean currents are given approximately in figure 2. The Labrador current with

its flow of cold water southwards by Newfoundland is of great importance, particularly for the temperature relations in certain parts of the investigated region.

A feature of the hydrographic relations which is of particular importance to our investigation is shown in figure 3, but does not appear in figure 2. South of the banks of Newfoundland, in the region between 48° and 50° west longitude, there is a marked " wedge " of cold water extending southward into the Gulf Stream. Exactly in this region of the sea the icebergs penetrate in the spring and summer. Below this " wedge " the water is much colder

FIGURE 3. Currents and ice boundaries near the Newfoundland Banks according to the steamer handbook for the Atlantic Ocean given in Schott's Geography of the Atlantic Ocean. The denser the streamlines of the Gulf Stream, the Labrador and the Cabot Streams (the last indicated by corrugated lines), the greater their velocity. The full drawn curves I to VI give the average boundary of the icebergs in June, the period of advance. The dotted curves VII to X from July to October, the period of retreat. The arrows in the same boundary indicate the direction of the advance and of the retreat and also by their relative length the velocity of these motions.

to considerable depths than the water on both sides of it, for the very cold bottom layers are pushed up towards the surface, a phenomenon of which we learn from the Michael Sars expedition in the year 1910. This cold " wedge " is shown by all our temperature charts encroaching upon the warmer water masses of the

Gulf Stream (see pls. 1 to 14). Westerly of the "wedge" one again finds the warmer waters of the Gulf Stream up to the neighborhood of the Continental Shelf of America, where the cold waters coming down from the north again produce their influence. For a more thorough understanding of the distribution of temperature of the surface of the ocean in February from 1898 to 1910 in the regions we have investigated (see fig. 5) we have attempted to draw a chart of the currents of the surface water in these parts of

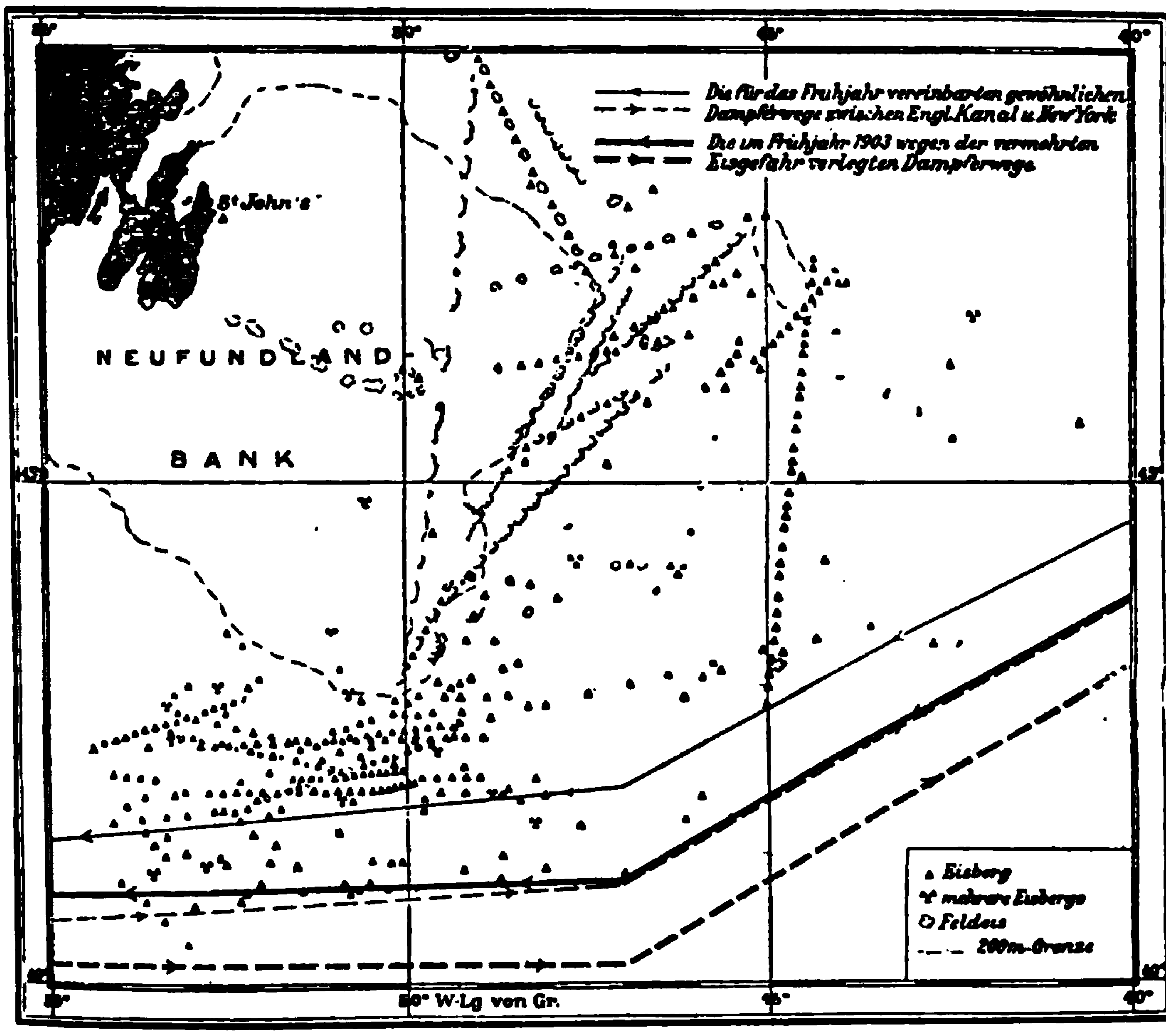

FIGURE 4. Distribution of drift ice and icebergs in the spring of 1903 that was very rich in ice, according to Schott's Geography of the Atlantic Ocean.

the ocean. For this purpose other investigations, particularly those of the Michael Sars expedition of the year 1910 have been employed. Our current chart (fig. 6) makes no pretension to do more than to sketch roughly the ocean current circuit in its principal features. The progress of the water masses through the ocean does not proceed by any such simple lines as these schematic current charts represent. It proceeds much more by monster moving eddy currents on the surface of the ocean and in the deeper layers. These whirlpools are in a great measure the cause of the extraor-

dinary tongue-like projections of the isotherms, not only at the surface of the ocean but in the underlying deeper layers. These come plainly into our charts (pls. 1 to 14) of the surface temperature in February and March in the different years, and also in the chart (fig. 5) where we have endeavored to give particular attention to these tongue-like features of the isotherms in the month of February for the interval which we have investigated.

Of particular interest are the current relations in the remarkable cold "wedge" which, as already has been said, penetrates

FIGURE 5. Average temperature of the ocean's surface in February, 1900 to 1910.

FIGURE 6. A schematic representation of the currents on the surface of the North Atlantic Ocean according to our understanding of them based principally upon the distribution of temperature and in part on the salinity.

southward into the warm water masses of the Gulf Stream, between 49° and 50° west longitude, and extending to the south of 40° north latitude. As is shown in our isotherm chart, figure 5, this "wedge" is exactly in the region of the most southerly corner of the Newfoundland Banks. This can be seen from the isobaths for 200 meters and for 1,000 meters appearing in figure 5. The "wedge" forms, so to say, a continuation of this corner towards the south, and follows essentially the course of the isobath for 4,000 meters as it makes its tongue-like extension towards the southeast (see fig. 1). During the Michael Sars expedition in the year 1910, a section of this "wedge" was taken (see Murray and

Hjort, 1912, p. 298). This section extends in a northwesterly direction from station 65 at 37° 12′ north latitude and 48° 30′ west longitude, to station 67 at 40° 17′ north latitude and 50° 39′ west longitude. According to this section, it has the appearance as if the water westward of the " wedge ", between the stations 66 and 67, moves approximately at right angles to this section, and then takes a more southwesterly direction as indicated by our surface charts. One may suppose that the water-masses in the deeper layers experience a deflection toward the right in consequence of the rotation of the earth and on that account move in a more southwesterly direction than at the surface.

The oblique course of the isotherms and lines of equal salt contents in the section and consequently also the lines of equal gravity show clearly and distinctly that the water masses on the west side of the " wedge " between stations 66 and 67 move with a great velocity in a southerly or southwesterly direction, and, further, that the velocities diminish from the surface toward the bottom. Between station 66, which lies in the middle of the " wedge," and station 65, the motion goes in an easterly or northeasterly direction, with diminishing velocity from above downwards. North of station 67, between this station and the Newfoundland Bank, the motion goes in an easterly direction with decreasing velocity downwards. The velocities were in all these cases very great, but the greatest lay between the stations 66 and 67. We explain these relations by the consideration that the water masses of the Gulf Stream, which flow with great velocity along the east side of America at the outer edge of the Continental shelf, experience a considerable resistance southwest of the Newfoundland Bank partly on account of the cold water-masses which are brought by the Labrador current from the north and partly because the Continental shelf south of Newfoundland has a strong trend towards the southeast. In the under water inlet thereby formed on the edge of the continental shelf, there are produced many eddies of cold and warm water-masses whereby the water of the Gulf Stream is compelled to bend towards the southeast. Exactly south of the most southerly corner of the Newfoundland Bank the current, in consequence of the contour of the ground and of the cold water-masses coming down from the north, meets great resistance. The warm current bends yet more toward the south and is thereby strongly narrowed and its velocity increased. While the warm water on the right side of this southerly moving current is depressed, the cold water lying

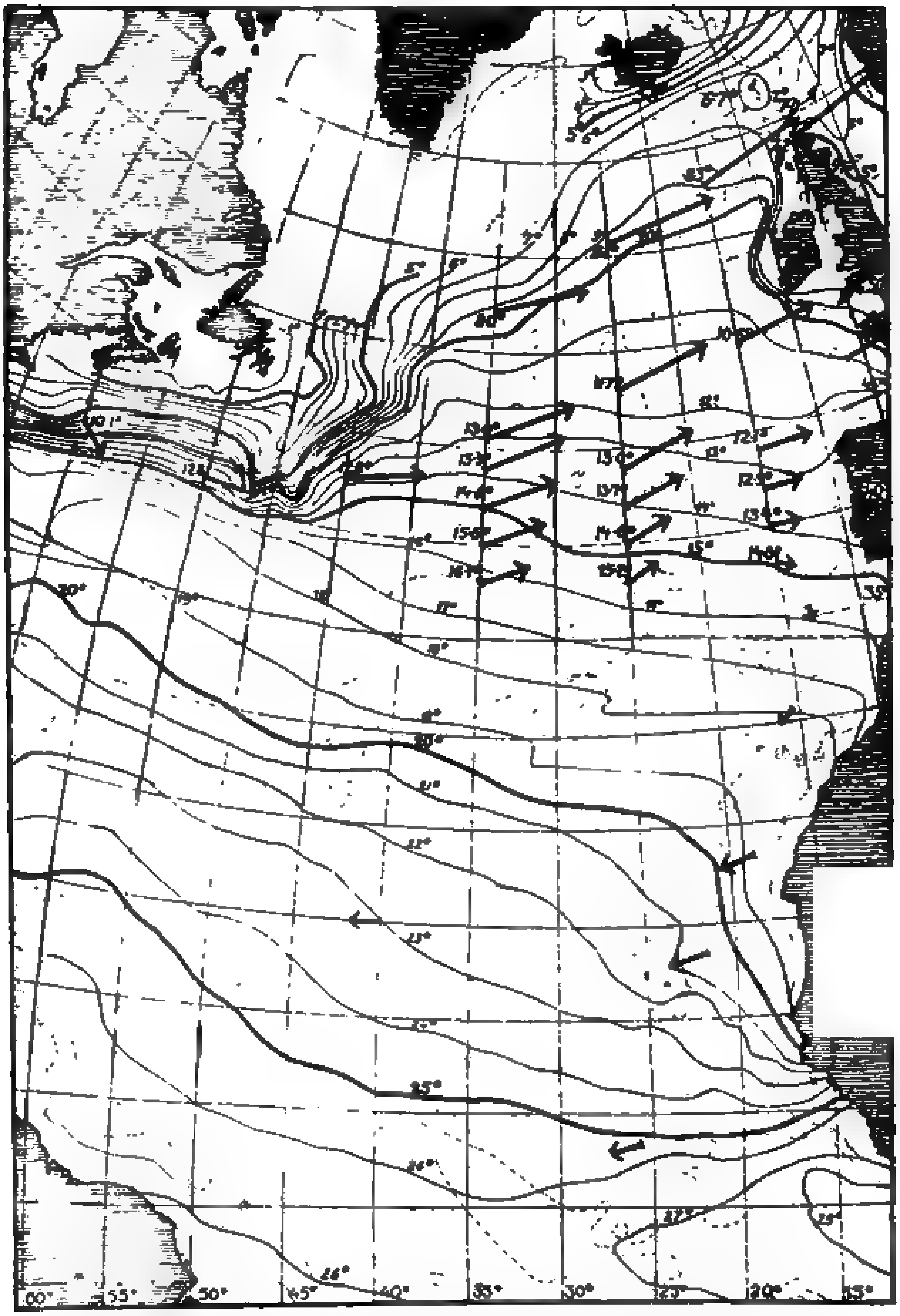

FIGURE 7. Average temperature of the ocean water on the surface in February as published in "Atlantischer Ozean" by the Deutsche Seewarte. The arrows give the direction of the isobars for January-February and the intensity of the air pressure gradients. The isobaths are the same as in figure 1.

below it is forced up on the left side of the stream and follows on southward with the cold surface water. On the other side of this cold "wedge" there goes according to our chart a warmer opposing stream to the northeast and north. These hypotheses are strengthened by the march of the isotherms.

We do not know with certainty the direction of the separate parts of the currents further eastward in their course through the Atlantic, and the current paths and eddies which we have indicated there must be regarded as somewhat hypothetical.

Figure 7 shows the distribution of the surface temperatures in February in the North Atlantic Ocean according to the representation given in "Atlantic Ocean" published by the Deutschen Seewarte in Hamburg, 1902. The figure shows also the mean temperatures which we have found for the three February decades from 1900 to 1910 for 10° fields of longitude in the region Portugal to Azores, and also for the similar 10° fields of the route Channel-New York. The mean of the latter is found from temperature values of the 2° fields previously mentioned which occur in the 10° intervals of longitude between 10° and 20° west longitude and between 20° and 30° west longitude. There is clearly a good agreement between these values and the ones represented by the isotherms published by the Seewarte. However, we may remark that our values for the eleven-year period 1900 to 1910 are somewhat lower in the eastern part of the ocean than those indicated by these isotherms.

We have also given the observed mean temperatures for February (1900-1910) for the 10° fields along the Danish routes north of 50° north latitude. They are mostly considerably lower than those corresponding to the isotherms. The isotherms for 10°, 9°, 8° and 7° C. should accordingly probably be moved somewhat further to the southeast between 40° and 10° west longitude.

On this chart (repeated in pl. 1) we give the above mentioned mean temperatures for the time interval 1900 to 1910 for each of the investigated 2° fields (where there were sufficient observations) on the route Channel-New York as well as the corresponding mean temperatures in the 10° fields in the region Portugal-Azores. Based upon these mean temperatures, we give also the isotherm for 8° C. and also those for each full degree between 10° and 16° C. As the reader will see, these do not differ in their course very much from the isotherms which appear on the charts issued by the Seewarte. In figure 5 we have endeavored to draw an isotherm

chart for the time interval 1900-1910. Here, however, we have not employed the mean temperatures for the single fields but have endeavored to determine an average form of the isotherms for each full degree for each year. In this we have taken account of the fact that these isotherms always show tongue-like forms, and that these alter somewhat from year to year. If one should compute isotherms from the mean temperatures for the whole time interval,

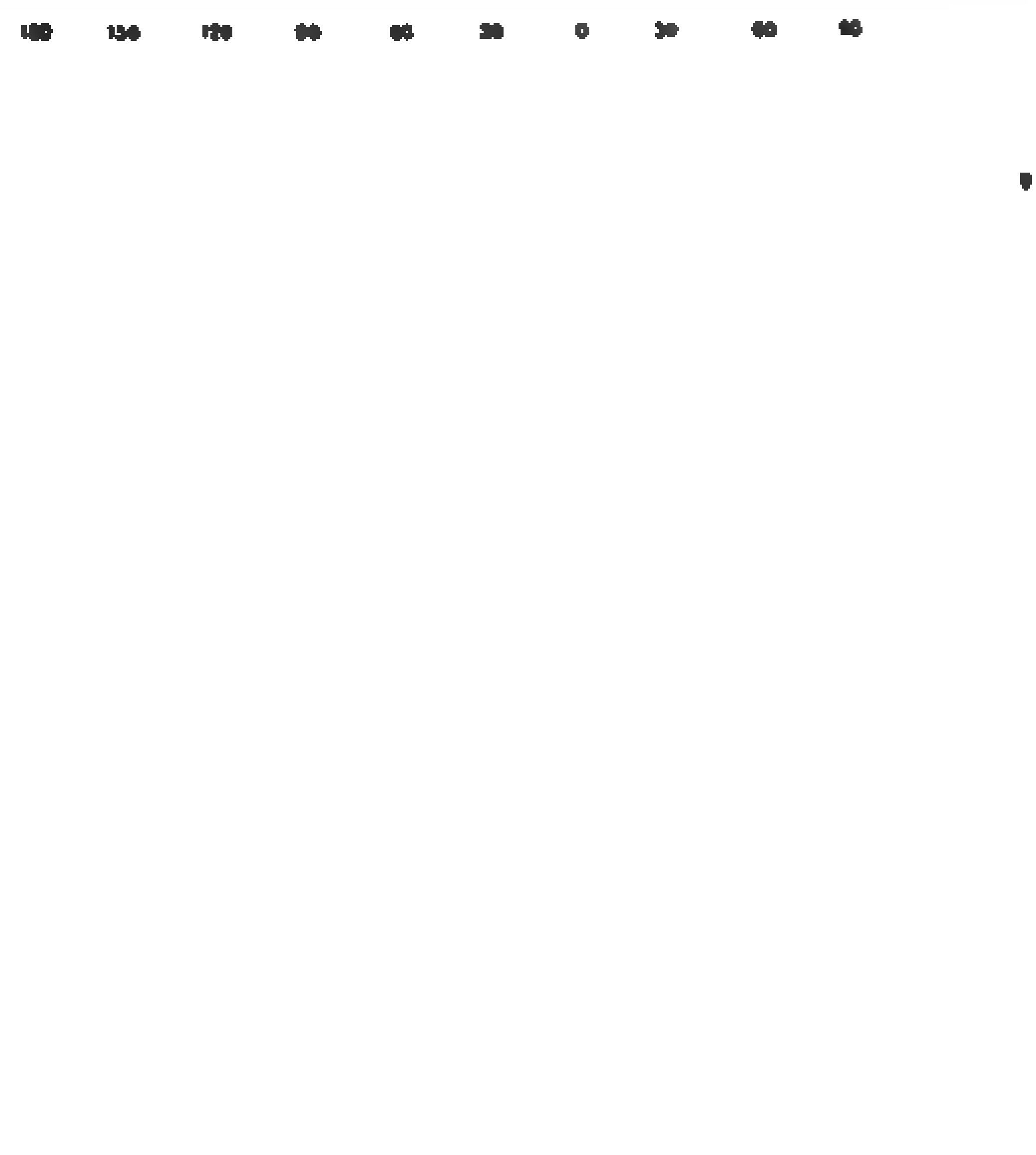

FIGURE 8. The wind conditions in the North Atlantic Ocean in January and February according to Angot's Météorologie and Hahn's Lehrbuch der Meteorologie. We have also drawn the isobars for February in the North Atlantic.

these tongues would more or less disappear. We have endeavored to determine the average position of each of these tongues, and although our result cannot claim great accuracy, yet we hope it may give a better general impression of the nature of the temperature distribution.

In plate 8 there is given a chart of the average temperatures and isotherms for the three decades, March 15 to April 13, for the time interval from 1900 to 1910, in accordance with our investigations.

The arrows in the chart in figure 7 and in plates 1 and 8 give the average direction and intensity of the wind (computed from the isobars as we shall later explain) for the months January and February, (see fig. 7 and pl. 1) and for March (pl. 8). We shall return to this in chapter VII.[1]

In this place we may state the following principal features of the average distribution of the air pressure and wind in the ocean region investigated, as they are shown in figure 8, which is taken principally from Angot's Meteorology.

FIGURE 9. Average temperature of the air in February according to the Atlas of the Deutsche Seewarte "Atlantischer Ozean."

Near south Greenland there is an air pressure minimum. A maximum region extends from the Spanish Inlet across over the Atlantic Ocean to the southern part of the United States. The actual maximum is generally found between the Madeiras and the Azores. Between these zones—that is to say, over the greater part of our investigated region—the wind is blowing towards the east and northeast. The northeast trade with the opposite direction is found only in the southeastern part of our investigated region. The

[1] The arrows do not give in fact exactly the winds, but the direction of the isobars. Their lengths indicate the magnitude of the air pressure gradients as computed according to the distance between the isobars. It is therefore not to be supposed that these arrows represent the actual winds either in direction or strength.

average wind velocity in the northern part of the region (Channel-New York) is comparatively great and considerably less in the southeast part between Portugal and the Azores. The distribution of air pressure and wind is approximately the same in March and February but in March it appears that the wind is on the whole somewhat more westerly and somewhat weaker in the region we have investigated than in February.

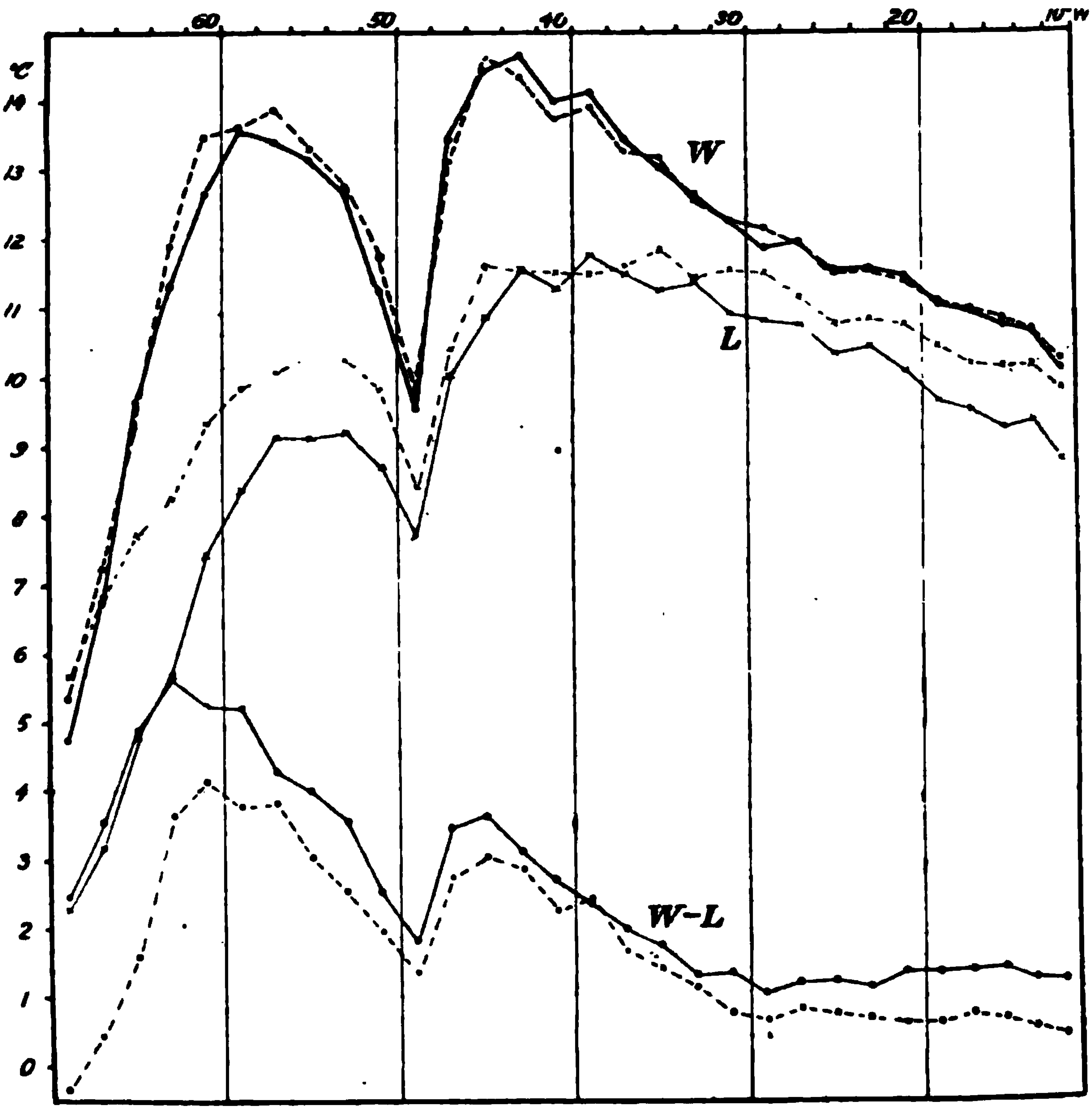

FIGURE 10. The mean surface temperature (W), air temperature (L), and the difference between these (W-L) for the 2° fields along the shipping course Channel to New York in the eleven-year period 1900 to 1911. The full drawn lines are for the first decade group (February 2 to March 4), the dotted lines for the last decade group (March 15 to April 13).

The average temperature of the air in February is given in the usual manner in figure 9. The isotherms for the air and the surface of the water follow in their principal features the same course, although in our investigated region the water on the whole is warmer than the air, particularly in February.

The cloudiness varies in February along the steamer route from the Channel to New York on the average between 6.5 and 7.8 on a scale of 10. In the southeasterly part of the investigated region (Portugal-Azores) the cloudiness diminishes from 7 at the northwest to 5-4 in the southeast on the coast of Portugal.

The frequency of precipitation in February has an average value during the whole interval covered by the observations between 10 and 20 per cent along the northerly steamship route, and between 5 and 18 per cent in the southern part of the investigated region. It is greatest in the northwestern and least in the southeastern portion of the region. In March both cloudiness and frequency of precipitation is somewhat less than in February.

The average temperature conditions in February and March-April, as we have found them for the eleven-year period 1900 to 1910 along the steamer pathway Channel-New York, are given in figure 10. The curves on this figure are based upon the mean values for our chosen 2° fields shown by cross-hatching in figure 1 and plate 15. In regions where two such fields adjoin one another in a north and south direction, we have given the mean value in our curves. In figure 10 the results for the three February decades are indicated by a full line and those of the second decade group (March 15 to April 13) by a dotted line. The curves " W " correspond to the surface temperatures " L " to the air temperatures, and " W-L " to the difference between the two. As the reader will see, the surface temperatures show a somewhat general increase from the east toward the west up to an absolute maximum about 44° west longitude of approximately 14.7° C. for both decade groups. From there the temperature sinks very rapidly to a minimum of 9.5° to 9.8° at about 49° west longitude. Further westward the temperature increases again to a maximum of 13.6° to 13.9° C. between 57° and 59° west longitude, and from there on towards the American coast it diminishes to a new value of about 5° C. The great falling off at 49° west longitude marks with great distinctness the above mentioned cold " wedge ". When one studies the temperature distribution in the single years, he finds that this " wedge " stays almost exactly in the same spot throughout. From both curves, (fig. 10) for the surface temperatures, we see that only a slight difference exists between the two decade groups. In the eastern part of the region the difference is particularly small. In the central part, it is on the whole in the last decade (March-April) somewhat colder than in the first (Feb-

ruary). In the western part it behaves oppositely, for the average is, on the whole, colder in February than in March-April. We shall return to speak of the temperature distributions from decade to decade, but here we mention briefly the other curves of figure 10.

The air temperature shows geographical changes similar to those of the water temperature. The "wedge" is very marked, with a temperature maximum on either side. While this "wedge" (at about 49° west longitude) has the same situation in the air as in the water, there is a small difference in the position of its maxi-

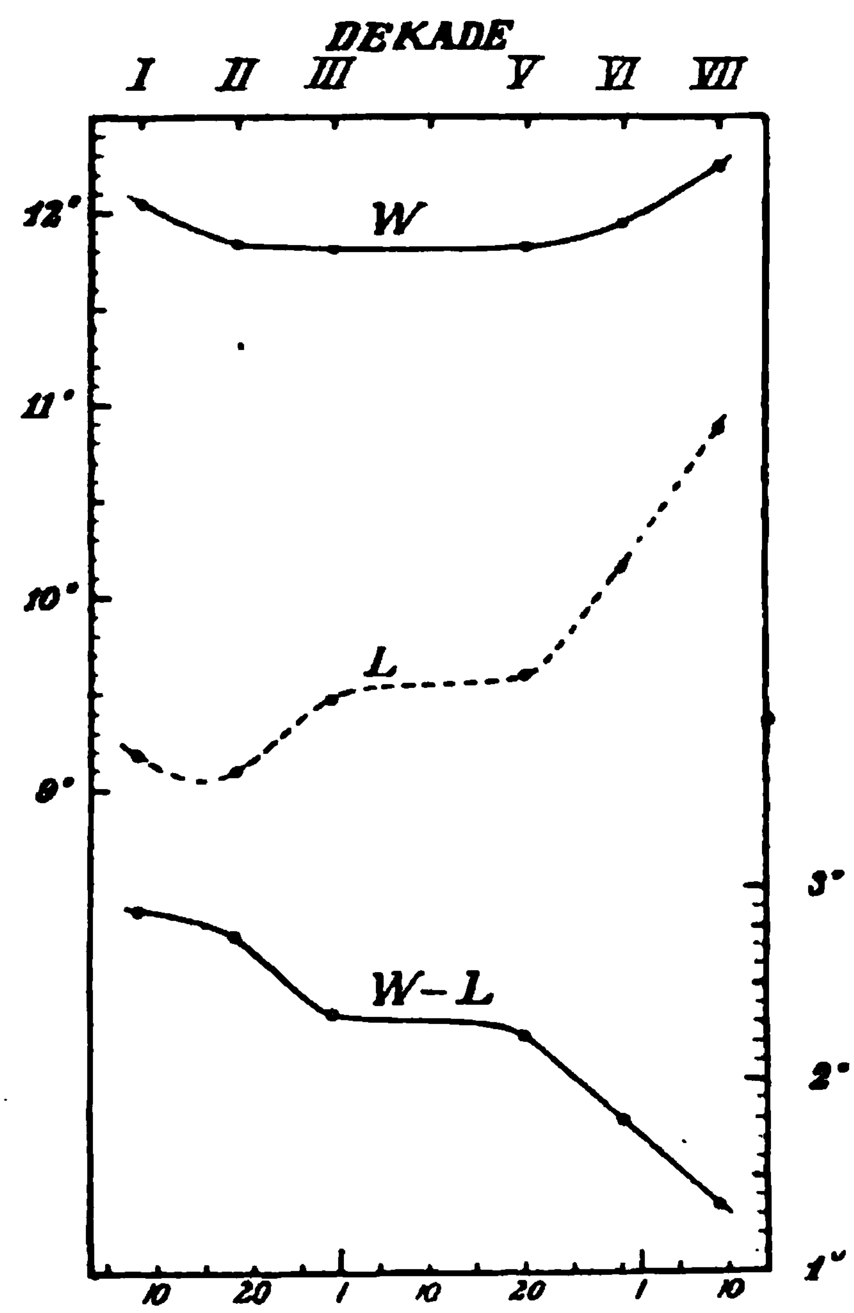

FIGURE 11. The curves represent the mean values for each decade (I-VII) for our combined 2° fields along the curves Channel to New York. W: surface temperatures; L: air temperatures, the scale on the right; W-L: surface temperatures minus air temperatures, scale on the right.

mum. For example, the greatest air temperature maximum of February lies at about 39° west longitude and is 11.8° C. and in March-April at 35° west longitude with a temperature of 11.9° C. The most westerly maximum, which is much less marked in the air than in the water, lies at 53° west longitude in February with a temperature of 9.2° C. and at 55° west longitude March-April with a temperature of 10.2° C. There is, therefore, a pretty well marked difference of temperature between the two decade groups, so that the February decade is considerably the colder.

The curves of surface temperature minus air temperature show, in general, a similar march to the other curves. First they rise from the east to the west, then show a well-marked minimum at the "wedge", then a new rise and a sudden fall towards the American coast. The difference between the temperature of the water and the air is in the easterly part of the region rather small, about 1.2° C. in February and 0.7° C. in March-April. Near 43° west longitude the difference is 3.6° and 3.0° C., while at 49° west longitude (in the "wedge") it is only 1.8° and 1.4° C. In contrast with the temperatures of the water and the air, this difference reaches an absolute maximum west of the "wedge" in 63° west longitude, giving in February 5.6° C., and at 61° west longitude in March-April with a difference of 4.2° C.

It is apparent that the difference between the temperatures of the water and the air in the first decade group is on the whole considerably greater than in the second. This is because the water reaches its temperature minimum considerably later than does the air. This feature is yet more clearly shown by comparison of the single decades.

In order to study the developments from decade to decade, we have combined the observations in the northerly steamer route in larger fields of 20° in longitude. The results are given in the following tables where our decades are designated by Roman figures. The temperatures are given as mean values of the eleven-year normals for all the chosen 2° fields (see fig. 1) which come within the 20° fields above mentioned.

In these tables we give the mean values for the three combined great fields. These mean values, therefore, indicate the temperature relations for the whole width of the Atlantic Ocean from the beginning of February until the middle of April. They are graphically represented in figures 11 and 12.

The *surface temperature* for the whole region shows a long extended minimum. The three decade values marked II, III and V, from the middle of February on to the second half of March are 11.84°, 11.82° and 11.83° C. The variations of these numbers are less than the margin of error. In general one can draw the conclusion that at this time a well-marked vertical convection exists. Great water masses, from the surface to very considerable depths, are being cooled, so that the variation of temperature of the surface is strongly damped. The consequence is that no well-marked temperature minimum can be recognized. This strongly supports our preliminary assumption that the surface temperatures in the second

MEAN TEMPERATURE FOR EACH DECADE.

A. Water.

	I	II	III	V	VI	VII
10–30° W.......	11.19	11.19	11.14	11.02	41.22	11.42
30–50° W.......	13.36	13.00	12.98	11.75	12.93	13.23
50–70° W.......	11.59	11.32	11.33	11.73	11.71	12.06
Mean.........	12.05	11.84	11.82	11.83	11.95	12.24

B. Air.

	I	II	III	V	VI	VII
10–30° W.......	9.98	9.91	9.99	10.02	10.54	11.12
30–50° W.......	10.92	10.29	10.74	10.29	10.87	11.71
50–70° W.......	6.63	7.70	7.10	8 50	9.08	9.83
Mean.........	9.18	9.10	9.48	9.60	10.16	10.89

C. Water Minus Air.

	I	II	III	V	VI	VII
10–30° W.......	1.21	1.28	1.15	1.0[illegible]	0.68	0.30
30–50° W.......	2.44	2.71	2.24	2.4[illegible]	2.06	1.52
50–70° W.......	4.96	4.22	3.63	3.2[illegible]	2.63	2.23
Mean.........	2.87	2.74	2.34	2.23	1.79	1.35

half of February and in the greater part of March form a trustworthy indication of the temperatures of the great water-masses. At the end of March the surface temperature begins to rise rather rapidly. There soon comes about a warm layer in the water, so that the surface temperature can no longer be regarded as an index of the temperature relations of the great water-masses lying beneath.

The *air temperatures* for the whole region show a sharply marked minimum in the middle of February, after which they rise rather rapidly to the first of March; but after that up to March 20, only small changes occur. Later the temperature rises again very rapidly. The peculiar form which the curve takes, (see fig. 11-L) with its horizontal course through the first three weeks of March, may be due to several causes. One might well suppose that our mean values are not good enough to give a very regular curve. And it is indeed possible that this is a reasonable explanation, for we are considering only a few tenths of a degree for the third and fifth decades. One cannot suppose that satisfactory decade values for the air temperature can be obtained from so short a series of observations as eleven years, and especially not when many of the decade mean values for the single years rest upon so few and so unsatisfactory

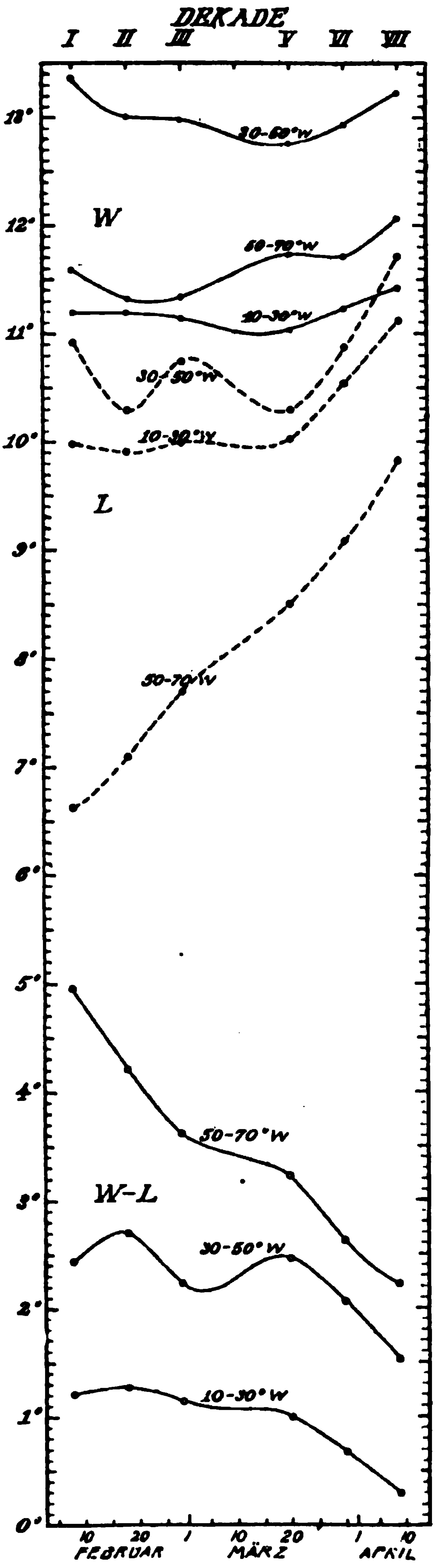

FIGURE 12. Curves as in figure 11 for the 2° fields between 10° and 30° west longitude, between 30° and 50° west longitude, and between 50° and 70° west longitude along the course Channel to New York.

observations, as is the case with our material. Nevertheless it is also well known that inversions of the air temperature frequently occur, and it not infrequently happens that in February after a rise of temperature, a new fall occurs, so that the decade mean values, even after a long series of observations, do not show a perfectly smooth march (see Hann 1911, p. 91).

Local irregularities of this kind, however, in a great degree disappear when, as we have done, the final mean values for a very great region are considered. We have taken the mean values for not less than forty-eight 2° fields in our computation of the values which occur in figure 11. In the study of the peculiarities inside the three 20° fields of longitude (see fig. 12) we find that the irregularity depends very largely upon the results of the middle fields which have a very marked secondary minimum in the fifth decade.

The difference between the temperatures of the water and of the air grows gradually less on the whole from the beginning of February to the end of April (see fig. 11, W-L). In the first three weeks of March, however, the difference remains about equally great, because then both the air temperature and the water temperature are substantially unchanged. The difference amounts on the whole to about 3° at the beginning of February, and not much more than 1° in the middle of April. In this there is, however, a good deal of local difference.

The tables show the difference in the temperature behavior in the three parts of the region as covered by the 20° fields of longitude, namely: the easterly part, from 10° to 30° west; the middle part, 30° to 50° west; and the western part 50° to 70° west—that is to say, west of the "wedge". The results are expressed graphically in figure 12.

In all decades the water and the air are both warmer in the middle part of the North Atlantic Ocean. The water is coldest toward the eastern part while the air is coldest toward the western part of the region. The difference between the air temperature and that of the water is greatest in the west and least in the east. The reason for this may be easily understood, for the middle part is under the control of the Gulf Stream, and is there not so strongly cooled. In the western part the cold water of the American coast, in large part the water of the Labrador current, mixes with the Gulf Stream water, so that the mean temperature is made lower. In the eastern part the water masses of the Gulf Stream have finally become cooled. The wind blows on the whole from America toward

Europe over that part of the Atlantic Ocean of which we are treating. The low continental winter temperature is particularly noticeable in the west, but the air is considerably warmed above the Gulf Stream and hence it also takes a higher temperature over the middle part of the ocean. This higher temperature sinks a little toward the European coast, but not so much as the temperature of the water-masses, which are cooled by outward radiation and by the air. Hence the difference between the temperature of the water and the air diminishes nearly uniformly from west to east. These results are distinctly seen in curves of figure 10, which relate to the single 2° fields. There also is seen another peculiarity. The relations of the cold "wedge" can easily be explained from this general view. Here the water comes from the north and is relatively very cold, while the air, on the other hand, comes in the greatest part from the west. It is already considerably warmed by the Gulf Stream water west of the cold "wedge". The air temperature therefore does not show so marked a minimum as the water temperature, and the consequence of this is that the difference between the water and air temperatures at this place is relatively small.

In the easterly and middle parts of the ocean, the surface temperature shows a minimum in the middle of March, but in the western part of the ocean the minimum comes toward the end of February. The curves for the temperature of the water (see fig. 12 W) have a comparatively regular course. A difference in some of the temperatures of a tenth of a degree or perhaps even less would be sufficient to make the curves completely regular.

The air temperature shows in the eastern part a long extended minimum from about February to the middle of March as shown in figure 12 L. In the western part the air temperature rises rapidly and gradually during the whole time and the minimum comes apparently in January. In the middle part, there are certain irregularities. Here there appear to be two equally low minima, one in the middle of February and one in the middle of March, with a well marked secondary maximum at about the first of March. In agreement with this the difference between the temperatures of the water and the air also shows irregularities (see fig. 12 W-L). If our mean values really correspond to the truth for this eleven-year period, the cause of this irregularity is probably that the above mentioned secondary depression in the air temperature is not smoothed out because there is not a sufficiently large number of

the years of observation. It is also apparent that the mean temperature of the air in the two other regions, the easterly and the westerly, in the third decade, that is from February 23 to March 4, is higher than would be expected. This feature may be recognized by the consideration of the curves for the whole Atlantic Ocean and most plainly appears in figure 11 (W, L and W-L) from the horizontal march of the curves for the time from March 1 to 20.

IV. EARLIER INVESTIGATIONS OF THE TEMPERATURE VARIATIONS OF THE ATLANTIC OCEAN

It has long since been recognized what a decisive thermal influence the so-called Gulf Stream has on the temperature behavior of the North Atlantic Ocean as well as on the climate of the west and northwest Europe. Hence it was apparent that a change in this ocean current would be of importance on the temperature of the Northeast Atlantic Ocean and the climatological relations of western Europe.

Prof. Otto Pettersson, in his well-known book on the relations between hydrographic and meteorological phenomena, (1896) made the first important investigations in order to determine the exact relation between the variations of the temperature of the ocean and the relations of air temperature and climate of Scandinavia and north Europe.

In the lack of continuous temperature measurements of the water-masses of the Gulf Stream itself, he took as the starting point of his investigation the temperature of the ocean at the surface near the lighthouses Utsire, Helliso and Ona on the Norwegian coast, where observations for a long period of years were available. In this he assumed that the variations in the temperature of the coast water depended directly on changes in the water-masses of the Gulf Stream which, now cooler, now warmer, are driven upon the coast. This assumption is, however, as we shall show later, not correct. The coast water in which these temperature measurements at the lighthouses were made is far different from the water that the Gulf Stream brings. As will later be shown, the surface temperatures, for example at Ona lighthouse, particularly in the winter months of January and February which Pettersson employed, depend completely on the relations of the winds along the coast which naturally also affect the wind relations to the temperature of Scandinavia, so that by this common influence a dependence between the two is brought about. As we shall see later, these

wind relations, that is to say, the distribution of the atmospheric pressure, exert a strong influence upon the variations in the surface temperatures of the Gulf Stream. It is quite another question as to whether these variations in the distribution of the air pressure in a greater or less degree depend upon the variations of the ocean currents and the masses of water brought on by them.

An important proof is furnished by Pettersson himself, for he showed a tendency toward continuity during long intervals of time in the variations of temperature both of the surface of the sea and of the air, so that anomalies of the monthly mean temperatures have exactly the same sign in a long succession of months. However, twice during the year, in the months of May-June and October-November there is a strong tendency to a break in this continuity. He showed further that the march of the anomalies in general from year to year shows a tendency to alternating rise and fall of the mean temperatures.

In later researches, "On the probability of periodic and non-periodic variations in the Atlantic Ocean currents and their relations to meteorological and biological phenomena" (1905, 1906), Pettersson attempted to show that a great yearly pulsation occurs in the Gulf Stream in the North Atlantic Ocean and in the warm Atlantic currents of the Norwegian sea, whose flows experience a strong minimum in the spring and a powerful maximum in autumn and towards the end of the year. This, as we understand it, he conceives to take place about simultaneously over the whole stretch of the ocean between the Azores and the Bering Sea. The cause of this pulsation Pettersson finds in the yearly melting of the ice as well in the antarctic as in the northern oceans. He conceives this action of the melting ice upon the different parts of the oceans of the world to be propagated by a series of peculiar deep waves. His conclusion appears to us in these points very doubtful and difficult to understand. We cannot find that the trustworthy observations which are at hand verify the assumption of a yearly pulsation of the Gulf Stream such as he proposes.[1]

[1] Pettersson has devoted a long discussion (1905) to the dynamic conditions in the Atlantic Ocean and the Indian Ocean and their relations to these variations. According to our view he has been misled by neglecting the rotation of the earth. On this account he omitted to note that the dynamic sections with their solenoids and their outward and inwardly directed forces, are able to establish comparatively stationary conditions in the water-masses which have their movement more or less at right angles to the direction of the sections and which are in lateral equilibrium. As an example of this conception may

Pettersson also tried to show that there are great variations from year to year in the Atlantic current of the Norwegian sea. These he regarded provisionally as non-periodic and also to be at least partially explained by variations in the melting of the ice. We have at several earlier opportunities taken issue with this ice-melting theory, and we will not go into it again at this place.

In his later works (1912, 1914) Pettersson believes himself to have shown that in the course of long intervals great changes in the climate of the earth take place (similar to those which Huntington maintains) and also in the circulation of the oceans. These changes he regards as in greater part periodic and due to cosmic causes. We should be led too far if we should undertake to examine these studies.

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be cited the condition of the Atlantic Ocean within and north of the Sargasso Sea. He says (1905, p. 27): "Between 26° and 30° north latitude, the water has an upward tendency, and on the surface the water flows on the one hand toward the equator and on the other toward the North Atlantic. The velocity in the latter direction is the largest, 47 cm. per second, that has been observed in the Atlantic Ocean. According to my view this lively water circulation is to be regarded as due to the influence of the melting of ice near Newfoundland. This important phenomenon for ocean circulation acts *periodically with the season of the year.* On account of the influence of the seasons upon the melting of the ice and the direction of the wind, the pressure and density distribution in the ocean can have no stationary condition." These consequences he bases upon Schott's longitude section through the Atlantic Ocean along the meridian of 30° east, which he has converted into a dynamic section. The steepness of the curves (of isotherms and lines of equal density) in this section north of the zone between 20° and 30° north latitude is obviously in a large part due to the eastward directed motion of the water masses of the Gulf Stream upon the north side of the Sargasso Sea. From this very steepness it results that the velocity of the currents is so large. By depressions or elevations of the lighter surface water on the right hand side of the ocean currents in the northern hemisphere (therefore on the inner side of the anticyclonic motion as in the Sargasso Sea) there is produced a heaping up,—that is, a depression of curves of the warmer surface water in the middle of this sea which Schott's section very plainly shows.

The "heaping up" of the ground water at the equator as well as the "cold up-rush" on the northwest coast of Africa and the "cold wall" on the east coast of North America, which according to Pettersson are due to hindrances in the motion of the ground water, are really examples of more or less stationary conditions which are produced because the colder lower layers at the left side of the ocean currents are pushed up in consequence of the operation of the rotation of the earth. The "cold wall" lies on the left side of the Gulf ᵓm along the east coast of North America. The "cold up-rush" on the ˈst coast of Africa lies on the left hand of the Canary current and the g up" of the ground water on the north side of the equator lies along side of the northerly equatorial current.

Especially Otto Pettersson's first cited work, "On the Relation Between Hydrographic and Meteorological Phenomena" have led to several valuable investigations on the change of ocean circulation and climate. As the most important among them we must mention at this point that of Prof. Dr. Wilhelm Meinardus.

After he had investigated the "Dependence of the Winter Climate in Middle and Northwestern Europe on the Gulf Stream" (1898) and the dependence between the variations in the air temperature on the Norwegian west coast at Christiansand in the autumn and the crop production in north Germany in the following summer, Meinardus, particularly in his work, "On the variations of the North Atlantic circulation and their consequences" (1904 and 1905), studied the dependence between the temperature variations in the ocean on the coast of Jutland and Norway and the distribution of air pressure over the North Atlantic Ocean. As an indicator of the last-named relation he used the air pressure difference in the successive years between Toronto, Canada, and Ivigtut in southwest Greenland for the years 1875 to 1900. Also that between Ponta Delgada on the Azores and Stykkisholm, Iceland, for the years 1866 to 1900, and also between Copenhagen and Stykkisholm in the years 1860 to 1909. Furthermore, he compared these results with the ice transportation by the Labrador current near Newfoundland.

Meinardus starts with the assumption that variations in the atmospheric pressure differences between Greenland and Iceland on the one side, and Canada, the Azores and Copenhagen on the other, correspond to similar alterations in the circulation in the ocean. Great air pressure differences correspond to increased ocean circulation and vice versa. He further supposes that when the Atlantic circulation in this way is increased, "it produces on oppsite shores of the Atlantic opposite influences on the transportation of heat by the ocean currents. By the acceleration of the Gulf Stream the temperature of the western coasts of Europe is increased, while by a simultaneous acceleration of the Labrador current its transportation of ice is increased and most probably the European temperatures are thereby diminished. With decreased water circulation opposite tendencies prevail." Meinardus takes no account of the displacements in the positions of the great air pressure maxima and minima or on the variations in their intensity. It can easily happen for example that the pressure minimum over the northern ocean may be particularly well-marked without being indicated by pressure dif-

ferences between the different land stations which Meinardus has chosen, for these may lie along nearly the same isobars. (This was, for example, the case in February, 1899, in 1904 and at other times, when the chosen air pressure differences were very small, the air circulation over the North Atlantic Ocean, however, very active, and this with very different consequences on the temperature of Europe.) Meinardus neglects to consider the effect of the possible changes in the wind directions in the different parts of the ocean. He supposes that, for example, an increased velocity of the wind over the Gulf Stream would increase its heat transportation and make the ocean warmer without considering that the increased wind might take a more westerly or northwesterly direction than is common.

Meinardus considers the variations of the surface temperatures on the Norwegian coast near the lighthouses Utsire, Helliso and Ona, where the coast waters are fairly mixed with the waters of the Baltic currents, and near Horns Riff on the west coast of Shetland where the intermixture of coast water is yet more strongly marked, in both cases to be due to the greater or less transportation of warm water by the Gulf Stream.

Although as we shall show later we cannot accept these assumptions, yet Meinardus' proofs of the dependence of the variations of the air pressure differences, the variations in the surface temperatures on the Norwegian coast, the heat of the upper layer of the ocean at Horns Riff, and also the variations in the transportation of ice by the Labrador stream are of great interest.

The relation between the air pressure distribution over the Atlantic Ocean, with its Icelandic minimum, and the variations in the velocity of the Gulf Stream or in the ocean circulation generally, Meinardus considers to be a closed chain of cause and effect. A more active Gulf Stream drift would make the ocean in the north warmer and a depression of the Icelandic air pressure minimum would be the consequence. This again would increase the air circulation and increase the velocity of the Gulf Stream, and vice versa. By these self-inductions he thinks that the tendency to steadiness in the temperature deviations, either positive or negative, through several months may be explained. But the secondary consequence is that cold ocean currents, particularly the Laborador current, will be increased by increased air circulation, or vice versa, and there [illegible] will be cooled, or vice versa, and hence [illegible] me the sea in the east and the north

will be cooled, or the contrary, and thus the reaction will be called forth.

In a later work, Meinardus treats of what he calls "Periodic variations of the ice drift near Iceland" (1906, see also 1908).[1]

The principal results at which Meinardus has arrived in these investigations are as follows: From a more vigorous Atlantic circulation, that is, a greater air pressure difference between Iceland and Europe in August to February, there follows:

1. Higher water temperatures on the European coast from November to April.

2. Higher air temperatures in middle Europe from February to April.

3. A greater quantity of ice near Newfoundland in the spring.

4. A diminution of ice near Iceland in the spring in comparison with preceding and following years.[2]

5. Good wheat and rye harvests in the west of Europe and in north Germany.

Attending weak Atlantic circulation, that is, small air pressure difference between Iceland and Europe in August to February, he finds the opposite conditions.

Meinardus thinks it improbable that the variations of the water-masses of the Labrador current have particular influence upon the temperature of the upper water layers of the Atlantic Ocean, since the cold and therefore heavier water of this current to the east and south of Newfoundland, must pass underneath the warmer though more salty water of the Gulf Stream. "Important mixture of the heterogeneous waters will perhaps take place in the lower layers of the Gulf Stream, but scarcely in its upper ones." On the other hand he believes that the icebergs produce a strong cooling action upon the upper water surface of the Gulf Stream, which occasionally is noticeable even on the west coast of Europe. As we shall see, this point of view is opposite to that of Schott. Schott was of the opinion that the temperature variations in the

[1] Grossmann (1908) gives a summary of the results of Meinardus and other earlier authors.

[2] This is relating, however, to the non-periodic variations of the single years in relation to neighboring years. For longer continuing periods of variation he finds (1906) on the other hand that the long periods of years of plentiful ice near Iceland coincide with relatively low air pressure upon Iceland and increased Atlantic circulation, while the periods of less ice on the other hand correspond with high air pressure over Iceland and weakened Atlantic circulation.

surface of the Atlantic Ocean could be attributed to variations in the Labrador current water-masses, but not to the ice whose influence he considered purely local.

In his well-known investigations on the action centers of the atmosphere H. Hildebrand Hildebrandsson (1897 to 1899) considers the influence of ocean currents upon the climate. He shows that the precipitation in winter at Thorshavn has the same character as the precipitation of the previous summer in St. Johns, Newfoundland, and also of the following summer in Berlin. He suggests that a mild and moist winter in northwest Europe may be produced by strong development of the barometric minimum between Iceland and Norway. A continuous air current from the southwest would then flow along the Gulf Stream. Such southwest winds would increase the velocity of this stream and thereby in all probability the temperature of the ocean surface would be raised.

If these things are so, says Hildebrandsson, it is apparent that if the winter precipitation in Thorshavn governs the precipitation of the following summer in Berlin, the precipitation of the previous spring and summer in Newfoundland would govern the precipitation at Thorshavn. Newfoundland lies not in the Gulf Stream but in the cold Labrador Stream. It may therefore be maintained that an increase of the Labrador Stream would tend to cool the Gulf Stream and that this cooling would be shown half a year later at Thorshavn. In this way the successive changes of precipitation found may be explained by variations of the North Atlantic Ocean currents.

At the same time, however, Hildebrandsson shows that for an interval of fifteen years a distinct correspondence persisted between the precipitation in winter in British Columbia on the Pacific coasts, and the rainfall of the following autumn in the Azores. In this case it seems to be shut out of the argument that the correspondence of the precipitation should be governed by ocean currents.

Hildebrandsson considers that it is yet too early to assign the causes of these phenomena. It can only be said with certainty that some action takes place between the atmosphere and the surfaces of the ocean and the continents so that a disturbance which occurs at one place produces noticeable effects very far away. The cause of a phenomenon must often be sought at great distances, even in the other hemisphere. It may be possible that it is not a simple accidental affair when long periods of drought occur in Europe in

the same years when the drift ice and icebergs of the Antarctic Ocean have wide distribution, and icebergs even drift as far north as the latitude of the Cape of Good Hope.

In later continuations of his work (1909, 1910, 1914) Hildebrandsson strongly maintains concerning the variations of air pressure, temperature and precipitation, particularly in winter, that there is a well-marked opposing relation between those action centers where there is an air pressure minimum and those where there is an air pressure maximum. Examples of such opposing centers are Iceland and the Azores, Alaska and Siberia, Tierra del Fuego and Tahiti. On the other hand a well-marked correspondence exists between the action centers of the same kind, as for example between the variations of the two air pressure maxima of the Azores and Siberia.

Hildebrandsson thinks that the principal cause of these variations which occur in opposing senses in the action centers of opposite kind, as for example air pressure minima and air pressure maxima, is not to be sought in the very regular tropical climates, and not even in the temperate zones. No such far-reaching phenomena of great variations from year to year are to be found in these, sufficient to be the cause of such considerable differences as exist between the different types. The cause must therefore, he thinks, be found in the polar oceans, in the condition of the polar ice. During a warm summer in the northern regions, according to his view, the ice is broken up and partially melted, and consequently in the next winter, in February and March, great masses of ice are common near Iceland. This reduces the temperature of the ocean between Iceland, Scotland and Norway, which again in its turn causes an increase of the air pressure in the same ocean region. This, again, influences not only the temperature in the parts of the earth which are directly affected by these action centers either in the same or opposite direction, but also action centers on the earth may be influenced at great distances.

How Hildebrandsson would explain that a warmer summer widens the distribution of the ice and on this account brings a greater quantity of ice to Iceland in the next following winter, he does not fully state. He does not appear to have observed that the variations in the distribution and the drift of the polar ice are influenced to a great extent by the variations in the prevailing winds, that is to say, in the distribution of air pressure, whereas the temperature has, directly, very little to do with it. The con-

sequence of a warm summer must be principally that more ice than common is melted, particularly in the ocean eastward of Greenland, and that the quantities of ice which may be available to drift southward towards Iceland are thereby diminished. The result therefore should follow the opposite direction from that which Hildebrandsson assumes. When he points for the proof of the accuracy of his assumption to the agreement between the temperature variations in northern Norway in summer and the temperature variations of Iceland in the fall and winter, it might be remarked we should expect such an agreement if, as Wojeikoff has indicated, alternate variations of yearly temperature take place in the odd and even years.

It may be seen that the principal cause which Hildebrandsson assumes for the variation of the ocean temperature eastward of Iceland is quite different from that which Hann has given, namely the variations in the northeast trade wind.

We shall not pursue further the details of Hildebrandsson's highly interesting investigation on the action centers, because we shall return to it in a later chapter when we speak of the great variations in the climate of the earth in general. We may, however, remark that Hildebrandsson suggests that climatic variations (especially variations of temperature) of a higher order occur which tend to overshadow these variations associated with the different action centers. Since these variations of the higher order are noted over the whole earth, they are regarded as having *cosmic causes* and one is apt from the first to think of them as *dependent upon the amount of radiation which the sun sends forth.*

H. N. Dickson (1901) has studied a great number of surface temperature observations collected by the common trade ships and dealing with the distribution of temperature and salt contents in the surface of the North Atlantic Ocean in each month of the year from the beginning of 1896 to the end of 1897. He believes himself to have shown thereby that great periodic seasonal changes and also non-periodic fluctuations take place in the circulation in the surface water of the Atlantic Ocean. These fluctuations appear to him to be associated with the distribution of air pressure and the circulation of the atmosphere, both as relates to the periodic seasonal changes and to the long periodic variations. In agreement with Pettersson and Meinardus, he thinks that the variations of the surface temperature of the ocean influence the distribution of the atmospheric pressure.

Along with Dickson's studies on the distribution of temperature and salt contents of the surface of the North Atlantic, one must classify the later investigations of the same kind made by J. Donald Mathews (1907) for the years 1904 and 1905, and also the international investigations which appear in the hydrographic bulletins published by the International Bureau in Copenhagen for the years after 1905.

Of interest from our standpoint is Prof. Gerhard Schott's treatise entitled "The Great Ice Drift by the Banks of Newfoundland and the Heat Distribution of the Ocean Water in the Year 1903" (1904) which was published two months after Meinardus' above-mentioned work on the variations of the North Atlantic circulation, in the same Journal (Ann. d. Hydr. und Mar. Meteor). Schott comes to the conclusion that the uncommonly great quantity of icebergs on the Newfoundland Bank in the spring of 1903 from March to July, and the generally low surface temperatures in the Atlantic Ocean (which according to his view was particularly great in the eastern part in the spring) were prinicpally to be ascribed to the variations in the intensity of the Gulf Stream and the Labrador Stream. He accounts for it in this way: that the increase of the velocity of the Gulf Stream must intensify the Labrador Stream, whereby the ice drift is intensified. The variation of the surface temperature of the ocean should be principally dependent, not upon the cooling action of the ice, but upon the extension of the cold water-masses which the intensified Labrador Stream brings down. The melting ice plays a negligible rôle in the great ocean and can have only local influence upon the cooling of it. For example, it is not to be supposed that "any direct action upon the temperature of western Europe can be produced thereby." We conclude, further, that the ice is not the cause but only a consequence or accompaniment of abnormal heat conditions and ocean current changes."

Schott, in agreement with Meinardus, attributed as the primary cause of the observed variations in the intensity of the ocean currents the winds depending upon the distribution of atmospheric pressure.

In the discussion of the surface temperatures recorded in ship log-books, and assembled for the different 1° fields of the ocean, Schott came to the conclusion that "the Gulf Stream made a very marked protrusion to the east in the spring of the year 1903 up to the middle of the ocean, with an accompanying increase of its heat and its velocity. This protrusion led on its part to an increase of the intensity of the cold Labrador current."

This protrusion of the Gulf Stream in the spring of 1903 was indicated by marked positive anomalies of the surface temperatures in the whole western part of the ocean. In February, the positive anomalies were most conspicuous in the fields westward of 60° west, although they were to be found also between 40° and 50° west. In March and April the anomalies were strongly increased, and spread eastward in the ocean to 45° west longitude in March, and even to 30° west longitude in April. After this they withdrew in a westerly direction and the principal part of the ocean was rather strongly below the normal temperature during the whole summer and the first part of the autumn.

Schott does not explain why such an increase of the activity of the Gulf Stream should have produced so strong an intensification of the much smaller and relatively inconsiderable Labrador Stream as to produce an end result of a powerful cooling of the surface of the Atlantic Ocean in almost its whole extent, instead of a warming of it, which would have been expected. Neither does he explain how it is that the Labrador current could distribute cold water-masses over the surface of the ocean, notwithstanding the fact, as Meinardus has brought out, that in consequence of increased density its water tends to sink below that of the warm Gulf Stream.

Let us now consider for comparison the results of our investigation of the surface temperatures in the same ocean region, Channel to New York, which Schott investigated. These give us a somewhat different picture from the results of Schott. The negative temperature anomalies are on the whole greater, and have a greater distribution over the surface of the ocean than he found in February and March up to April, and there is in these months no appearance of such an increase of the activity of the Gulf Stream as he describes. Not only in the eastern part of the ocean in February (see pl. 26), but also in all the western part between 60° and 70° west longitude we find positive anomalies in February as well as in March and April. Although there is a progressive increase in these westerly positive anomalies in these months, it finds no extension eastward. It even happens that in the neighboring fields, between 50° and 60° west, there is an increase of negative anomaly from February to March-April, as well as in the whole ocean eastwards (see pls. 27, 26, the curve W below and fig. 20, and No. 41 of the curves for 1903).

These discrepancies between Schott's results and ours appear the more noteworthy since at least in a great part we have used

the same observational material from the ships' log-books of the Deutschen Seewarte as he did. By comparison of the temperatures of the single fields which Schott gives in his charts for February, 1903, in plate 18, with our material, we find considerable deviations (see our pl. 4 and Schott's pl. 18). Unfortunately Schott has not given the number of observations for the single fields, but since we have given among others temperatures for a whole series of fields where he gives none in his charts, we must assume that our material is a good deal richer than his, and on that account gives more trustworthy indications.

Besides, we believe that our process in assembling the observations in 2° fields is more advantageous than his assembly in 1° fields, especially where the number of observations at each field is so small as here. Else a single erroneous observation plays too large a part. From our own material we believe that we can see that in a whole series of temperature values in different fields Schott has employed only a single observation.

However, this consideration does not suffice in order to explain all the difference between his result and ours. For this we must call attention to the fact that he has obtained his normal temperatures for the single fields from "Quadratarbeit" of the Deutschen Seewarte, whereas we obtained our normal temperatures from the reduction of all observations of the eleven-year period, 1900 to 1910. Furthermore, we have used for the computation of the temperature anomalies only the temperature normals from the series of 48 fields where we found that the number of the observations of the different years was great enough so that one might expect that they would really give good values. Thus we hope that we have results which give a trustworthy picture of the march of the distribution of temperature variations. That this is indeed the case appears, as we have already remarked, since the different curves show close similarity between themselves.

According to the results which are afforded by the discussion of our observation material we think that we may safely say that in the time from the beginning of February to the middle of April, 1903, no such increase in the strength of the Gulf Stream was present as Prof. Schott supposes. On the other hand, the surface temperatures were in all ocean regions from 60° west and eastward to about 25° west in February considerably below the normal. Even in the western part of this region, that is to say, between 50° and 60° west, the surface temperature of the water was uncommonly

cold, much colder than in previous years, with the exception of 1899. The already low temperature sank considerably lower in March and April over the whole region from 60° west, eastward to about 10° west. To be sure there was during this time, as we have remarked, a strong increase of temperature anomalies (from +0.3° C, to +1.7° C.) in the most western fields between 60° and 70° west. But this cannot easily be explained by any intensification of the Gulf Stream, for if that had been the case the neighboring fields, between 50° and 60° west, would have felt the influence, and in these there were abnormally low temperatures and a depression in the anomalies from —1.8° C. in February to —2.1° C. in March-April.

Dr. Wilhelm Brennecke has investigated the "Relations between air pressure distribution and the ice conditions of the ocean eastward of Greenland" for the year 1904. Prof. G. Schott has treated of "The boundaries of the drift ice near the Newfoundland Banks" in 1904, and finally Dr. L. Mecking has studied "The ice drift from the region of Baffins Bay as controlled by current and weather" (1905), "The drift ice phenomena near Newfoundland and their dependence on climatic relations" (1907). The principal results of these different investigations are as follows:

1. The variations in the ice drift as well in the east Greenland polar current as in the Labrador current depend upon variations in the distribution of air pressure.

2. On these grounds the variations from year to year in the ice conditions near Newfoundland and Iceland usually go in opposite senses. That is to say, a strong ice drift near Newfoundland is attended by simultaneous weak ice drift near Iceland and vice versa.

3. The melted ice water near Newfoundland has no apparent direct influence on the temperature of the ocean near the western European coast.

4. In years of very great quantities of ice in the east Greenland sea there appears to be a diminution as well of the surface temperature of this sea as also of the air temperature in March up to May in Iceland and in the northern parts of Europe, as shown at Bodo on the Norwegian coast and in a less degree at Copenhagen. In years of little ice the temperature is always higher than in normal years. In years of extraordinarily great quantities of ice in the east Greenland sea there is also a low surface temperature in the sea near the east coast of Iceland (Papey), near the Faroe

Islands (Thorshavn) and near the Norwegian coast (Ona and Andenes).

Prof. Hann (1904-5) has studied the relation between the variations of temperature of northwestern and middle Europe, at Greenwich, Brussels, and Vienna. A. Buchan had recognized in the year 1867 the dependence between the air-pressure anomalies in Stykkisholm and the air-temperature anomalies over the British Isles. He showed that the cold period in the year 1867 in Scotland coincided with high air pressure over Iceland and northern Scotland and low air pressure over the channel in southwest Europe, while the great heat of July, 1868, in Scotland coincided with uncommonly low air pressure at Stykkisholm and high air pressure over Scotland. The latter correlation occurred also in September, 1865. By investigations over a long period of years, Hann came to the conclusion that "an intensification of the air pressure minimum near Iceland is attended by increase of the winter temperature over northwest and middle Europe, while a diminution of it produces a lowering of the same. In how far the intensity of this North Atlantic barometric minimum depends on the positive or negative temperature anomalies of the ocean water in the North Atlantic is a question which cannot be touched upon in this investigation. Such a dependence is in a high degree probable but it is very difficult to recognize and separate the cause and effect in the matter. On one point we may, however, remark. While the anomaly of the ocean temperature is often longer than a whole year of the same sign, the air-pressure anomaly at Iceland varies much oftener. The anomaly of the ocean temperature and that of the air-pressure often differ in sense." In the summer months he finds the relation between the air pressure in Iceland and the temperature in Europe alternate, as would indeed be expected.

In this paper Hann investigated also the relation between the variations in the two action centers of the atmosphere over the North Atlantic Ocean. That is to say, he compared the air pressures in the region of minimum near Iceland and the region of high pressure near the Azores, and found that in a majority of cases relatively lower pressure in Iceland (Stykkisholm) coincided with relatively high air pressure in the Azores (Ponta Delgada). Conversely, low air pressure in Ponta Delgada occurred with relatively high air pressure in Stykkisholm. This dependence, he thinks to explain, at least in part, since a high pressure in the Azores must generally fall with "an increased activity of the atmospheric cir-

culation. If the northeast trade blows more strongly than usual it would tend to displace the maximum towards the right. Thereby the atmospheric cyclone over the North Atlantic Ocean would be intensified with attendant intensifications of the air pressure minimum of its center near Iceland. Intensified high pressure near the Azores and the dependent intensification of the air pressure minimum near Iceland can therefore be connected as cause and effect."

Prof. Gossmann has studied "The Relation Between the Temperatures of the North Atlantic Ocean and of the Northwest and Middle Europe" (1908), and particularly in how far this relation may be used for temperature forecasting. He cites liberally from earlier investigations of the same matter. He seems to have assumed erroneously that variations in the surface temperature of the water along the Norwegian coast are directly connected with the variations in the Gulf Stream. In an investigation covering a long series of years, he comes to the conclusion that a temperature forecast for north Europe based upon the temperature of the sea on the Norwegian coast will in general be less trustworthy than a forecast which is based on the local temperature conditions of the different places. Such a forecast may be based on the previously noted tendency to a continuation in the same sense of the temperature deviations and the changes of temperatures from month to month and partially also from quarter to quarter, which would furnish certain conditions for temperature forecast. As he appears to have incorrectly assumed that the variations in the surface temperature of the water along the Norwegian coast coincide with variations in the Gulf Stream, he comes to the conclusion "that the variations of the temperatures of the Gulf Stream cannot be directly the cause of the phenomenon (that is to say, of the conservational tendency of the temperature deviations, etc.). We must associate it rather with a conservational tendency of the air pressure distribution."

Grossmann thinks that before one may accept as a sufficient explanation the reciprocal action between the ocean temperature and the air pressure distribution to which Meinardus called attention, it must at least be shown "that the observed differences of ocean temperature are sufficient in their influence to produce the differences in the air pressure distribution which are revealed in the mean values of the air pressure differences as well as in the charts of air pressure distribution for different periods." Gross-

mann inclines "toward the view that besides the reactions of air pressure distribution and ocean temperature described by Meinardus, there is in operation a more powerful higher cause which we do not yet understand. It is this which calls forth both the continuity and the periodic discontinuity, or as we might better say, the changeability of the air pressure distribution, and thereby induces the parallelism of the ocean and air temperatures as a consequence of it."

The variations in the temperature of the ocean and their connection with the variations in the air pressure distribution over the northern regions and in the air temperature in Europe are investigated in the above mentioned treatises only with the help of the yearly observations of the surface temperature of the water along the Norwegian coast and the coast of Jutland. Only in later years have the variations of the surface temperature in the Atlantic Ocean itself been methodically investigated.

Here we must give first place to Dr. Johannes Petersen's treatise entitled "Non-periodic temperature variations in the Gulf Stream and their relation to the air pressure distribution" (1910). This is based on the observational material of the Deutschen Seewarte for the same region along the course Channel to New York, which we have investigated. Petersen has twelve stations along this route, with an interval of about 5° of longitude between these stations.[1]

Each station consists of a 1° field (covering 1° in longitude and 1° in latitude) within which all the observations for each month of the year were assembled (without regard to the decades) and for the twenty years from 1883 to 1902. This arrangement has the weakness that with such small fields the number of observations even for a whole month together is too small in order to give trustworthy values, particularly in regions where the variations are very great. The number of observations for each station per month, says Petersen, varied between five and twenty, but nevertheless there were many gaps. His observational material for the time February to April was considerably less than that which we have employed, on which account the temperature curves for his individual stations show on the whole a less good agreement than the curves for our individual

[1] The situations of the observation stations are as follows:

Station	1	2	3	4	5	6	7	8	9	10	11	12
Longitude W.	12°	17°	22°	27°	31°	36°	41°	46°	51°	56°	61°	66°
Latitude Jan.-July	49°	49°	48°	47°	46°	45°	43°	41°	41°	40°	40°	40°
Latitude Aug.-Dec.	50°	50°	50°	49°	49°	48°	47°	46°	45°	44°	42°	41°

2° longitude fields, hence we must suppose that in all probability our results are more accurate than his.

If we draw the curves for February and March for Petersen's individual stations or 1° fields, we see that these curves compared with ours agree well in the eastern stations but not so well, especially for March, the further one goes toward the west. If we compare the two series for the first and second decade groups for the

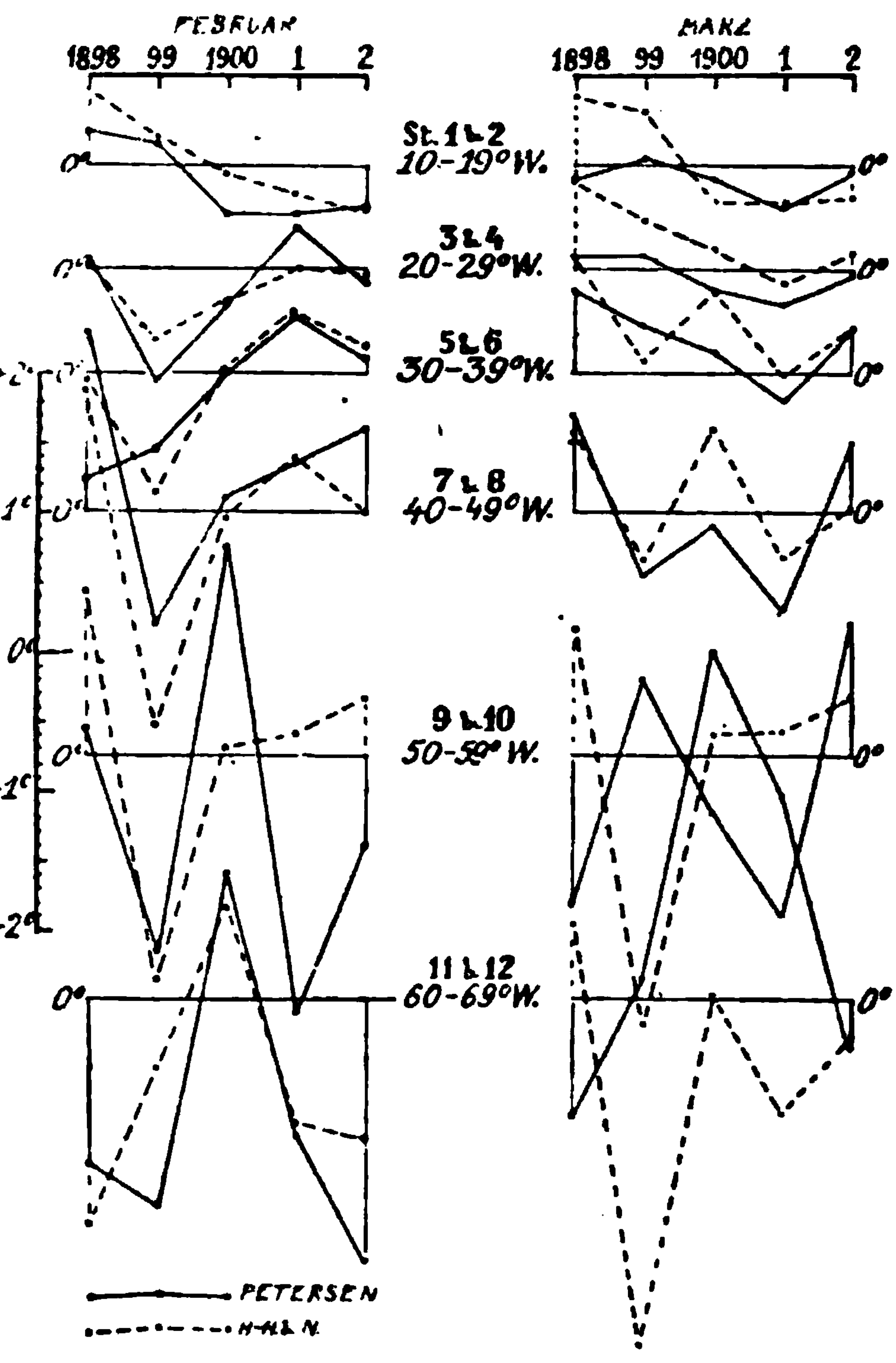

FIGURE 13. Curves for the temperature anomalies for February and March 1898 to 1902 at Petersen's 2 by 2 stations by pairs (the full drawn lines) with the anomaly curves for our 10° fields for February and March-April (dotted lines) combined.

years 1898 to 1902, where we both have observations, we find a very good agreement between the curves of Petersen's most eastern field station 1, (that is between 12° and 13° west longitude and 49° and 50° north latitude) and those for our fields between 12° and 14° west longitude and 49° and 50° north latitude. But for the fields westward of this the agreement is less satisfying and becomes worse the further towards the west one goes until west 41° the agreement

apparently disappears. That is, however, what one must expect. In the eastern regions the relations of the individual fields are so similar that even a few observations in a small field are sufficient to furnish a fairly good mean value, while for the more variable region further westward a much more extensive observational material is necessary, and for this purpose, as we have seen, 1° fields are not adequate.

If one forms the mean of the temperature anomalies, taking Petersen's stations two by two which lie within our 10° longitude fields (between 10° and 20° west longitude, etc.) it would be expected that more trustworthy values in comparison with ours would be obtained. In figure 13 the full curves show results found in this way for Petersen's stations for February and March from 1898 to 1902, and the dotted lines give the corresponding curves for our 10° longitude fields. The agreement is better, especially in the eastern fields, than we had expected.

In comparing the Petersen curves for March with ours for the last decade group, one should not forget that these last extend from March 15 to April 13 and the times for the curves do not fall together, which in part explains their discrepancies. But it does not explain the extraordinary deviation between the curves for the field 50° to 59° west longitude. In this field our curves for the first and last decade groups for the years 1898 to 1902 fall almost exactly together and we seem justified in supposing therefore that during the time intervening the same relations must hold in this region. There is therefore no place for the great disagreement which Petersen's curves show, and we must conclude that these are not representative.

The principal result of Petersen's investigations is that the yearly variations in the surface temperatures of the Atlantic Ocean depend on the air pressure distribution, which controls the winds. He has, however, made no attempt to reduce this relation to a quantitative basis.

He finds that the changes of position of the Icelandic air pressure minimum are of great importance for the variations of the surface temperatures in the Atlantic Ocean. He says "the non-periodic changes of the position of the Icelandic depression cause corresponding variations in the direction of the wind, which, after one or two months interval, express themselves by the increase or diminution of the ocean temperatures. Thus, for example, a very westerly position of the depression calls forth, by means of the wind, high tem-

peratures in the East Atlantic Ocean. An abnormally eastern position on the other hand brings about low temperatures. If the abnormal distribution of the air pressure is particularly strongly marked it makes itself felt in the temperatures of the whole extent of the ocean. Otherwise opposite temperature departures occur on the opposite shores."

Petersen comes to the important conclusion that the variations in the Gulf Stream influence directly the Icelandic air pressure minimum; but not so much—as Meinardus had assumed—in that they themselves increase or diminish its intensity by means of systems of self-inducing force, but that they alter the situation of it. An intensified Gulf Stream drift leads greater quantities of heat into the Norwegian Ocean, warms the air, generates an air pressure minimum and draws thereby the Icelandic minimum towards the east. In this way more westerly and northwesterly winds are generated in the Atlantic Ocean, which tend to hinder the Gulf Stream. If, however, the Gulf Stream in consequence of these flows more weakly, this has the opposite influence and the Icelandic minimum has a tendency to retreat towards Greenland. As an accompanying phenomenon it occurs that when the Gulf Stream is weakened, then the cold east Greenland current, which is its compensation current, flows slower and extends less far than commonly. In this way the Icelandic air pressure minimum may more easily be pressed back toward the west into a relatively warmer region and so the cyclical process begins again. In this way it is that "the Gulf Stream by means of its indwelling forces regulates its own transportation of heat and forms a current which alternates between a time of strong flow and a time of weak flow."

Petersen thinks that his tables on the temperature anomalies at his twelve stations in the twelve months of the year prove the impossibility of the assumption that variations in the surface temperatures can be produced "by variations in temperatures of tropical waters which are carried along through the Atlantic water circulation throughout its whole course with the velocity of the water flow." One sees no such movement of negative or positive anomalies from one station toward the other. He may be right in maintaining that most variations are not thus caused, but he has not proved that they can never be caused in this way. He ignores in his conclusion the source of error that without proof he has assumed that the water masses move from west towards east in the same direction as his steamer lines. If on the contrary the current goes at right angles

to or in some degree obliquely to them his consequence would be erroneous and his temperatures anomalies for the twelve stations would prove little either in one direction or the other.

Petersen found further that the deviations in the surface temperatures of the North Atlantic Ocean have a well marked tendency to swing about an axis in the center of the ocean at about 40° west

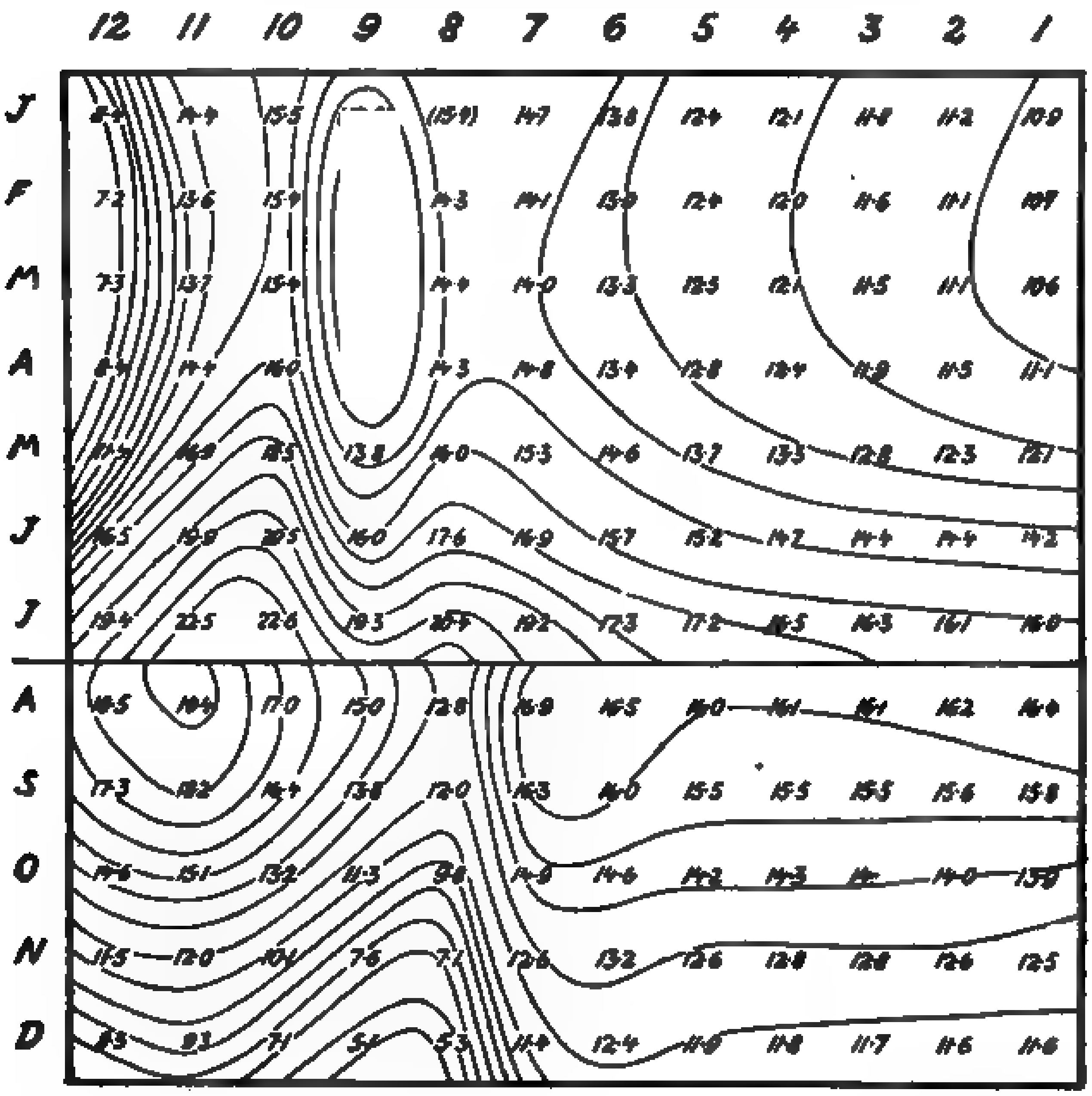

FIGURE 14. Isopleth diagram of the average temperatures for each month of the year (J-D) at J. Petersen's twelve stations (1 to 12) along the abscissae.

longitude in such a way that the temperature deviations eastward and westward of this axis are of opposite sign. Petersen's observational material is, however, not sufficiently complete and satisfactory to prove such a conclusion, particularly for the western fields.

Petersen's investigations have interest for us in that they embrace all the months of the year, and we can therefore follow the march of the average temperatures from month to month. In figure 14

we have given an isoplethic diagram drawn from the mean temperatures for each month at each of his stations. It is to be noticed here that in the months January to July the observations along the southern steamer route, that is to say, the winter course between the English Channel and New York, are given, and that is the same course for which the most of our observations are found. From August to December they follow the northern route, that is to say, the summer route, which is considerably farther north, particularly in the middle part of the ocean, where the difference for example at 40° west longitude amounts to 4° in latitude and at 46° west longitude, 5° in latitude. This explains the break in the values which occurs between July and August and also between December and January.

We see that in the months January to July the minimum is at station No. 9, at 51° west longitude and 41° north latitude, while from August to December it falls at station 8, eastward of this at about 46° west longitude and 46° north latitude. The explanation is easily apparent, for station 9 is upon the southern route immediately on the west side of the earlier mentioned "cold wedge" due to the Labrador current. Since this region of cold Labrador water follows the eastern declivity of the Newfoundland Bank from northeast toward southwest, it is plain that if we go further north to the northern steamer route, the region of minimum temperature must be found further eastward near station No. 8.

On the whole, this isopleth diagram gives a good representation of the principal features of the distribution and change of temperature for the year in this entire oceanic region.

Dr. H. Liepe in his paper entitled "Temperature Variations of the Surface of the Ocean from Ouessant to St. Pauls Rock" (1911) has investigated the variations of eight stations during the 20-year period from 1884 to 1903. These were 1° fields which he chose in the most frequented shipping routes along the east side of the Atlantic Ocean, from the English Channel and southwards towards St. Paul near the equator (see pl. 15, I-VIII). In the same manner as Petersen, Liepe assembled for each month all observations of the surface temperatures within 1° fields as given by the ships' log-books of the Deutschen Seewarte. The number of the observations within the different fields varied a great deal. On the average there were about 17 observations a month for each of the eight 1° fields, and the highest number of observations for one field during a month reached 46. An under limit of five observations per month was fixed.

The march of temperatures found by Liepe for his eight stations gives the impression that he obtained more accurate values than those of Petersen for the single stations since the curves for the different stations agree better (see fig. 15). Compared with our curves for the years common to the two series of observations, that is from 1898 to 1903, there is a good correspondence in the curves for our eastern and southeastern fields concerning

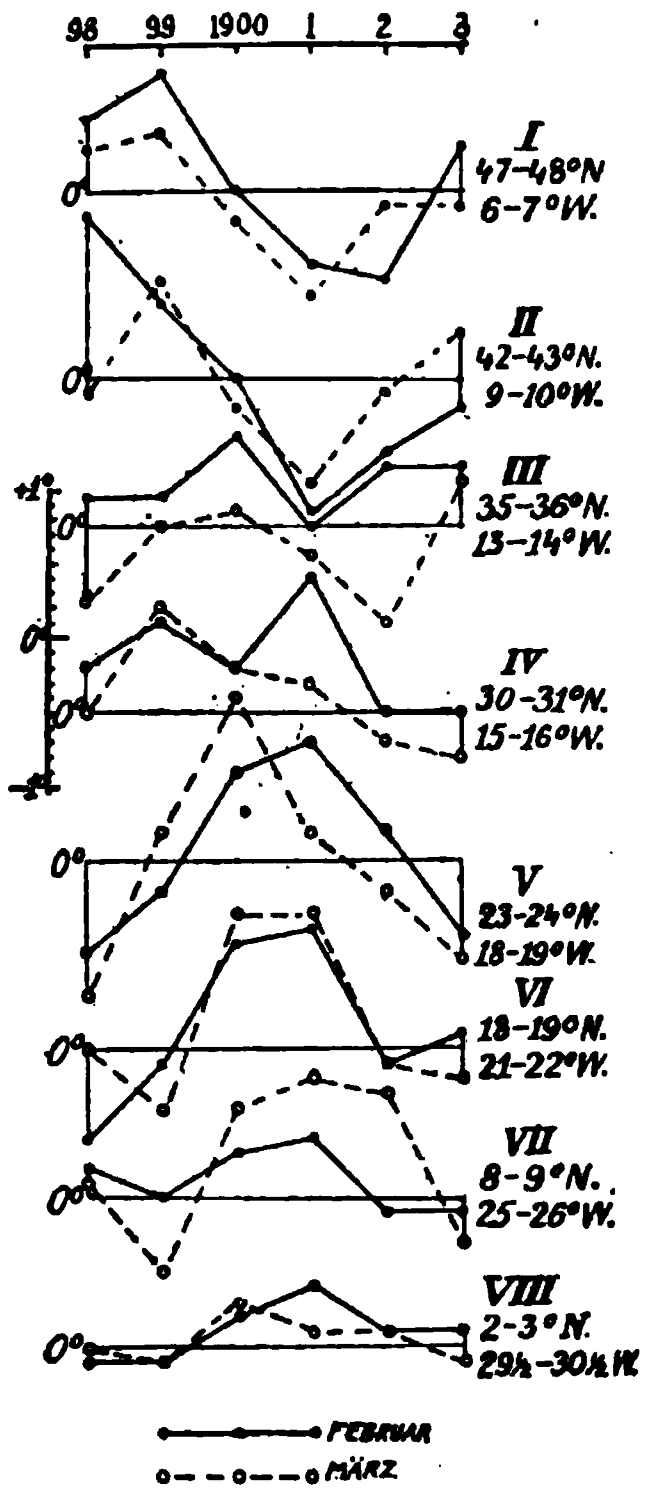

FIGURE 15. Curves for the anomalies of the surface temperatures at Liepe's stations I to VIII for February and March, 1898 to 1903.

which we shall speak again. This was to be expected, because the hydrographic relations in the region investigated by Liepe are much more regular than in the greater part of the region investigated by Petersen, and in this respect Liepe's region is similar to our eastern and southeastern one.

The principal conclusion of Liepe in relation to the causes of the variations agrees with Petersen's view that they are to be referred to the winds.

For his three most northerly stations between 35° and 38° north latitude it is the variation in the *direction* of the wind which principally influences the variations of the surface temperature of the sea, sometimes in the same month, but sometimes in the month following. He says "the strength of the winds acts for these stations as an intensifying, but not a causal factor. ·On the other hand, within the trades and especially for stations 4 to 6, between 18° and 31° north latitude, the *strength* of the wind is the principal cause, since the direction of the trades may be looked upon in general as pretty constant. The effect of varying strength of northeast trade winds shows itself in the following month, or the next but one, while that of the southeast trades is first noted in the following year, in the surface temperatures of the stations mentioned."

Although Liepe is of the opinion that the winds on the whole produce a fairly quick and local influence which may be different simultaneously in different parts of the ocean, he seems also to assume that, for example, the depression of the surface temperature, at least in part, is to be ascribed to the transportation of cold water masses from considerable distances over the ocean. He says, for example (1911, p. 480), that "the existence of uncommonly great quantities of drift ice and icebergs in the Labrador Stream in combination with a northwesterly direction of the wind may have tended to favor the formation of the so strongly marked negative anomaly of temperature which appears in these stations on the French and Spanish coasts." He seems even to believe that an increased melting of ice in the Arctic regions attending a strong increase of warm water from the Gulf may be effective in depressing the surface temperature of the stations. We have to assume that he attributes this to the transportation of cold ice water over the Atlantic Ocean with a mixing with the Gulf Stream water, although he does not express himself clearly to this effect.

It is interesting to note the good agreement between the yearly curves for the surface temperature at Liepe's station No. 1 and Petersen's station No. 1, which have been assembled by Dr. Peter-
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Dr. Engeler's work entitled "Periodic and Non-Periodic Temperature Variations of the Benguela Current" (1910) may be mentioned here since it is concerned with the variations of the surface temperatures of the eastern part of the South Atlantic Ocean, similar to those which we have hitherto discussed in the North Atlantic Ocean. His investigations extend over the years 1891 to 1898 and are based upon observations along the German sailing ship route, round the south end of Africa, as well as those of the English steamer route between Cape Colony and Europe. He finds great variations of the surface temperatures from year to year, with well marked maximum and minimum periods, and these come for the most part about the same time in the whole investigated region. He thinks that these variations cannot be attributed to non-periodic incursions of cold water-masses from the Antarctic Ocean since the effect of these must be gradually spread northward between the southern and northern part of the investigated ocean current and could not affect both of its branches simultaneously.

On the other hand he thinks that strong ice drift with quantities of icebergs in the South Atlantic Ocean may have produced in single periods as in the years 1893 and 1894 a certain influence on the variations, and have tended to limit the maximum periods and intensify the minima. It is little remarkable that he does not note that this action which he must also attribute to the extension of cold water northwards must have made itself most felt in the southerly part of the current rather than in the northern exactly as if it depended upon intrusion of cold water-masses from the Antarctic ice ocean, unless he assumes an intervention of the air temperature.

Engeler attributes as the principal cause of the variations of the surface temperature of the Benguela Current "the non-periodic variations of the intensity of the southeast trade winds with which they are associated in an unbroken chain of cause and effect." By an increase or diminishing of the strength of the trades, the transportation of currents of cold water is increased or diminished and the surface temperature correspondingly sinks or rises.

He thinks that another influence of winds of non-periodically varying intensity may lie in the fact, that in consequence of the greater circulation of the waters an uprise of cold water from the bottom must take place in the current, since the greater velocities must hinder the approach of water-masses from the south. "Such a moment occurs naturally at all points of the current simultaneously. Which of these two processes has the principal influence

cannot be decided with certainty." The last remark can scarcely be entirely correct, for the action cannot be equally strongly distributed at all times, but must be greatest behind the stronger winds.

The only published observations on variations of the intensity of the southeast trade winds relate to St. Helena, for the years 1892 to 1898 and are very insufficient for a proper comparison between the relations of the wind and temperature variations. They can only give certain qualitative impressions without elevating the investigation to a quantitative basis.

W. Köppen has investigated the question "On What is the High Temperature of Europe and the North Atlantic Dependent?" (1911). He arrives at the conclusion that in part at least the variations of the yearly seasons depend upon the cloudiness which in Europe is greatest in the winter and least in summer, both conditions tending to an increase of the temperature. Furthermore, he attributes a part to the prevailing winds which are southwesterly. Of far the most considerable influence on the high temperature in Europe are the warm ocean currents which bathe the west and northwest coast. Köppen does not deal with the periodic and nonperiodic variations, but contents himself with a statement that it has long been known that the simple nearness of warm water and its action on climate is not decisive, but that the direction of prevailing winds makes it influential. He says, "their influence can only be felt when it is borne by the winds." He thinks besides that there cannot yet be accurately estimated the relative effects on the warming of Europe of the different factors, the water-masses of the Gulf Stream, the prevailing winds, and the cloudiness, even though one should be satisfied with a rough approximation.

Commander Campbell Hepworth, (1910) compared the variation in the surface temperature in the North Atlantic with the variation of the strength of the trade winds. He is of the opinion that there is a distinct dependence between the two, and such that variations in the strength of the northeast and southeast trade winds in a series of months or in a single month are roughly mirrored by the distribu

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of the westerly winds. Furthermore he is of the opinion that the length of time is variable which is required for the influence of the variations in the strength of the trade winds to make itself felt in the North Atlantic Ocean through the medium of the Equatorial Current.

In a later work (1912 and 1914) Campbell Hepworth has investigated the relation between the variations of the Labrador Stream, the variations of the surface temperature of the North Atlantic Ocean, and the variations of the air pressure and temperature over the British Isles. He believes he has established a certain connection between the three kinds of variation, although one must say that this dependence is somewhat far-fetched and often yields to other stronger influences which make themselves apparent. The agreement between his curves for these variations is therefore not very striking and his results are not particularly convincing.

P. H. Galle has compared in two papers (1915 and 1916) the relations between the variations in the strength of the North Atlantic trade winds and the variations in the height of the water and the temperature in the North European seas as well as the variations in the winter temperature of Europe. He comes to the conclusion that there is a connection between these. But the agreement between the variations of the strength of the trade wind and the variations of the height of the water of the North Sea, which he shows, is not very great. Also the agreement between the variations of the trade wind and the variations of the surface temperature of the northern European seas is not particularly striking. His comparison of the variations of strength of the trades and the variations of the winter temperature of certain parts of Europe leads to better agreement. It has been shown by several authors, that this latter is in a great measure influenced by the air pressure distribution over the Atlantic Ocean and Europe and also that the variations of these pressure distributions depend in a certain degree on the variations in the trade winds. Hence it is not improbable that the trade wind is the original cause.

Galle claims, as Campbell Hepworth also maintained, that a slight connection exists between the strength of the trade winds and the temperature of the British Isles, but it is indeed very small. Campbell Hepworth found a phase displacement of about fourteen months, while Galle estimated it as only two months.

V. THE VARIATIONS IN THE SURFACE TEMPERATURE

As already noted, our curves (figs. 16 to 19) for the temperature anomalies of the ocean surface in the single 2° longitude fields in the whole eastern part of the investigated region show a marked agreement over great regions. The different characteristic lines, which indicate the variations, change from field to field by a gradual march as one looks forward, for example, from the east toward the west. Among prominent common features may be noted the depression in the year 1904, which appears on all the eastern curves for the first decade group February 3 to March 4, particularly from 10° west longitude to 40° west longitude, and in part even to 50° west longitude. An equal depression is found in the curve for the second decade group (March 15 to April 13), in the eastern part of the investigated region. But further toward the west the greatest depression occurs in the year 1903.

In common for a considerable part of the curves as well for the first as for the second decade groups, is also a depression occurring in the year 1899. The curves tend toward a maximum in the year 1901. Further on the temperature generally rises strongly from the year 1904 with small breaks to the years 1906, 1907 and 1908.

The curves for the single 2° fields westward of 44° and 46° west longitude at 41° north latitude show apparently only slight correspondence, and our figures 17 to 19 are calculated to give an impression of a chaotic medley of lines with no similarity. That these irregularities begin at about 46° west depends upon the fact that here a certain great discontinuity in temperature of the fields occurs from temperatures about 13° or 14° C. to between 6.8° and 8.5° C. The irregularities in the curves westward of this boundary have clearly as their cause the fact that in this part of the ocean the isotherms for the ocean temperatures lie so closely together that a comparatively slight difference of locality even within the same 2° fields is sufficient to produce a great temperature change, so that the distribution of the observations within the field may have a great influence on the mean value. Besides this, it occurs that inaccuracies in the determination of the position of the observer may produce a noticeable influence in this region. Furthermore, slight local movements of the water surface may easily produce changes in the surface temperature in such localities.

It is moreover probable that many accidental errors may play a part in the computed mean values for the single fields, even when the number of observations is quite large. More than a moderately

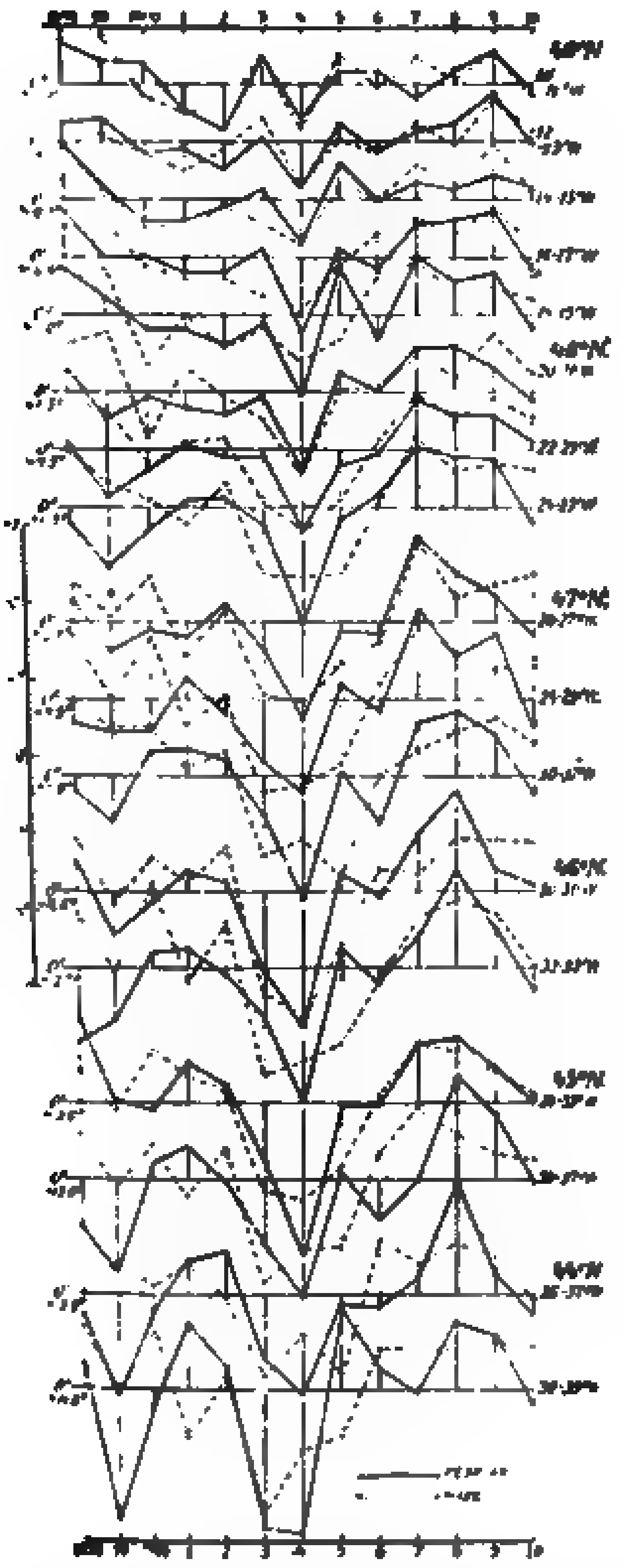

FIGURE 16.

FIGURE 17.

FIGURES 16 and 17. Curves for the temperature anomalies of the surface at the single 2° longitude fields between 10° and 56° west longitude, 50° and 41° north latitude for February (full drawn lines) and March-April (dotted lines) for the years 1898 to 1900. The scale of figure 16 at the left is twice as great as of figure 17 at the right.

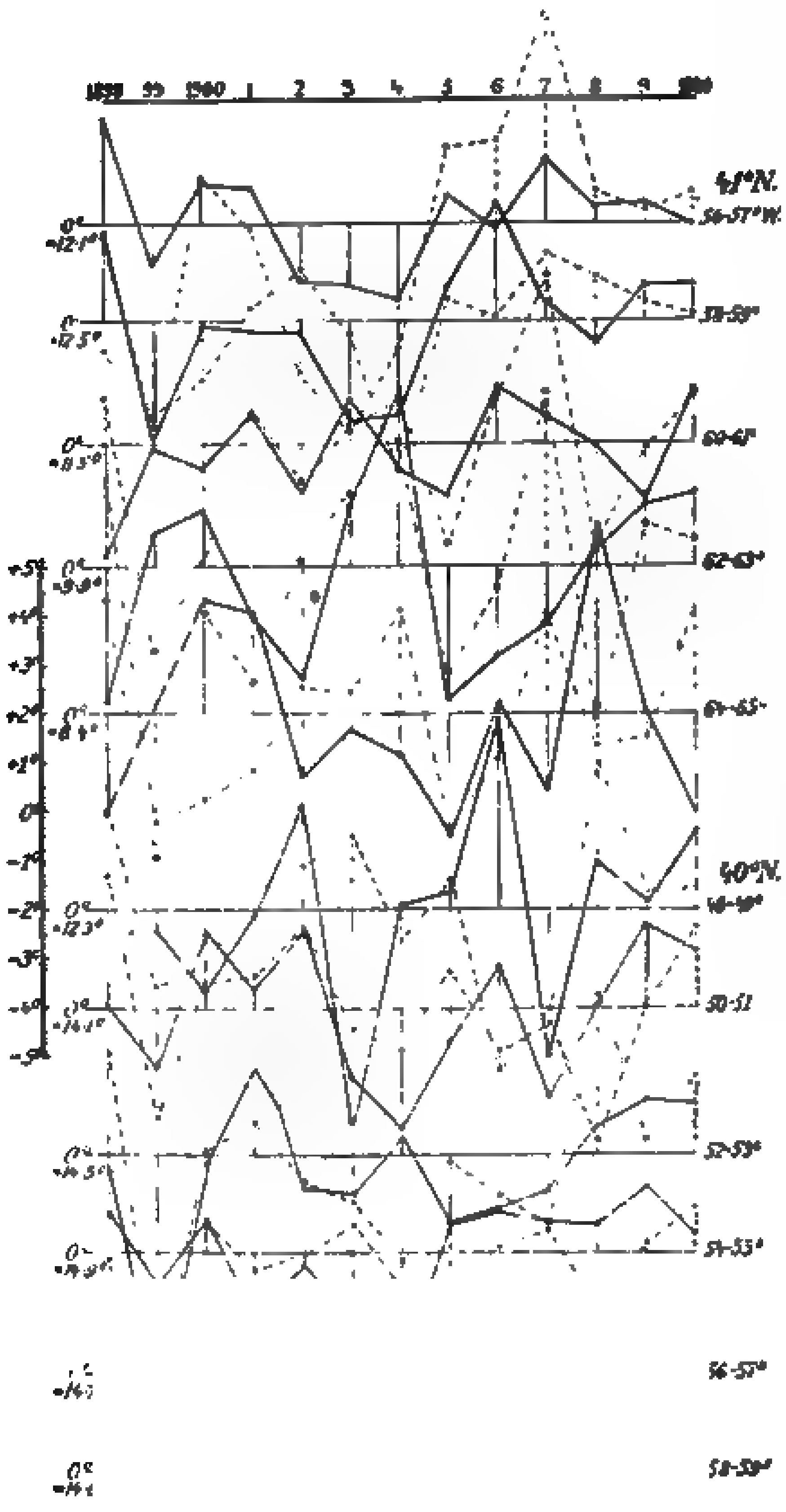

FIGURE 18. Continuation of figure 17. Curves for fields between 48° and 66° west longitude, 42° and 40° north latitude.

good agreement between the single curves for the fields is therefore not to be expected. These curves each by itself can make no pretense that it represents with absolute correctness the conditions of its region.

However, it is clear that representative values may be obtained by taking the mean for the 2° fields over a considerable region. We have, as we have already said, therefore divided our whole northerly region between 10° and 70° west longitude in six fields, each of 10° longitude. Within each of these 10° longitude fields, we have taken

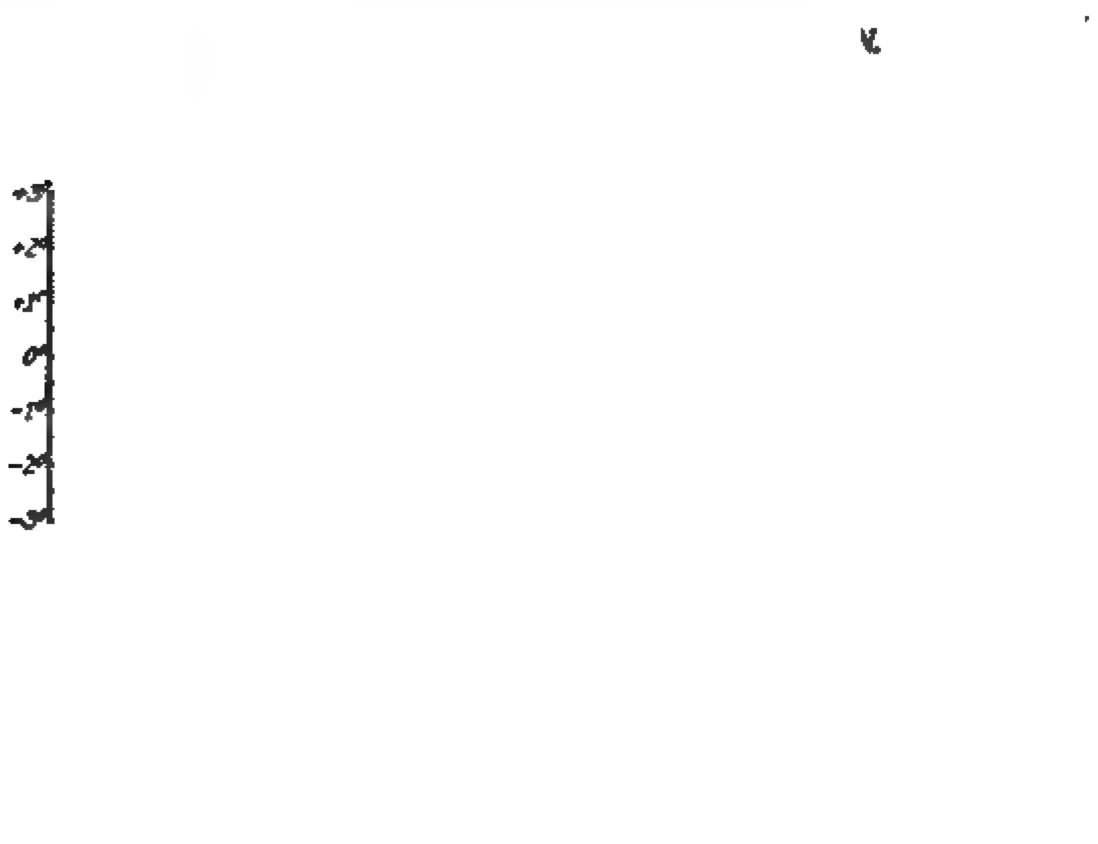

FIGURE 19. Continuation of figure 18. Curves for fields between 60° and 70° west longitude, 40° and 41° north latitude.

the mean of the anomalies of the mean temperatures of the chosen 2° fields. The temperature anomalies thus obtained for both decade groups are given in table 2-W and are graphically expressed by the curves in figure 20. These curves show a great correspondence, and it is therefore doubtless to be assumed that they correspond to the actual temperature relations.

This applies also for the field between 50° and 60° west longitude where the curves for the single 2° fields are somewhat irregular. Among other things the correspondence between the curves of the first and the second decade groups for these 10° longitude fields warrants the belief that the variations which they show depend in

23 and 25, the mean temperatures found in this way for the 4° longitude fields for each year and for each decade group are given. In figures 24 and 26 are given the corresponding average tempera-

Februar.

18

19

FIGURE 23. Temperatures of the 4° longitude fields along the shipping course Channel to New York in the first decade group February 3 to March 4, 1898 to 1910.

Februar.

1898
99
1900
01
02
03
04
05
06
07
08
09
10

FIGURE 24. Temperature anomalies of the same 4° longitude fields and for the same time as in figure 23.

ture anomalies carried out to tenths of a degree. The vertical bold-faced numbers represent positive anomalies, the inclined figures negative ones. Iso-anomalies are given for each degree, the full lines for positive anomalies, the dotted lines for negative ones. The fields with positive anomalies are indicated by cross-hatching.

März-April.

18

19

FIGURE 25. Temperatures of the same 4° longitude fields as in figure 23 in the second decade group March 15 to April 13, 1898 to 1910.

März—April.

1898
99
1900
01
02
03
04
05
06
07
08
09
10

FIGURE 26. Temperature anomalies for the same 4° longitude fields and for the same time as in figure 23.

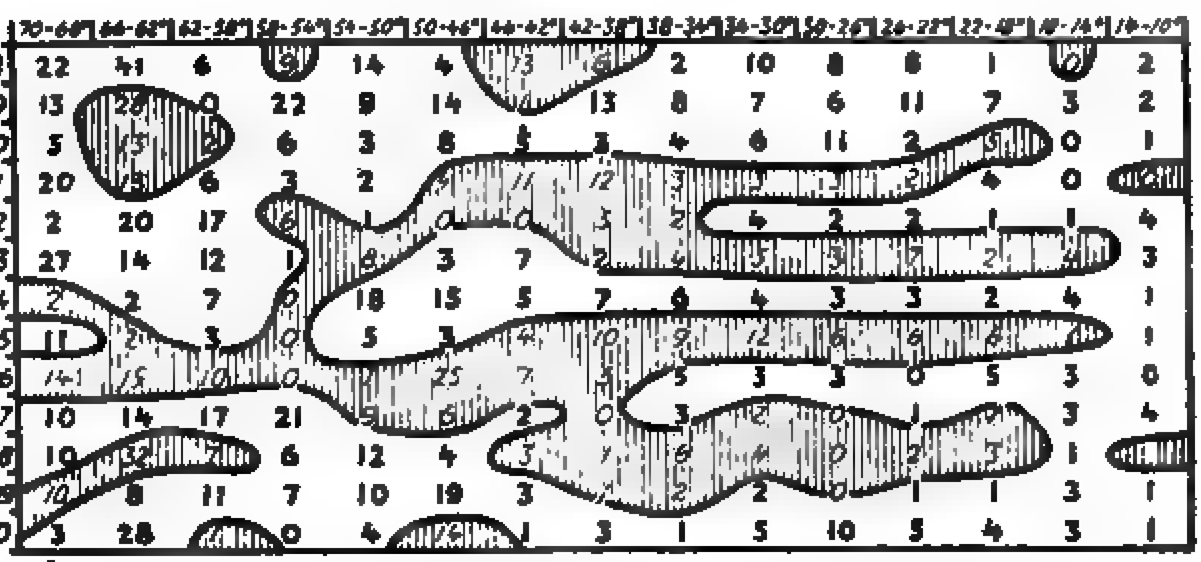

FIGURE 27. Difference of the surface temperatures in tenths of a degree Centigrade in February and March-April for 4° longitude fields along the shipping course Channel to New York. 14 designates warming from February to March-April, *14* designates cooling.

These isopleths give a very clear presentation of the distribution of the temperature variation as well for the places as for the times. There is well marked agreement between them. We find that the great minimum in the years 1903 and 1904 both in the first

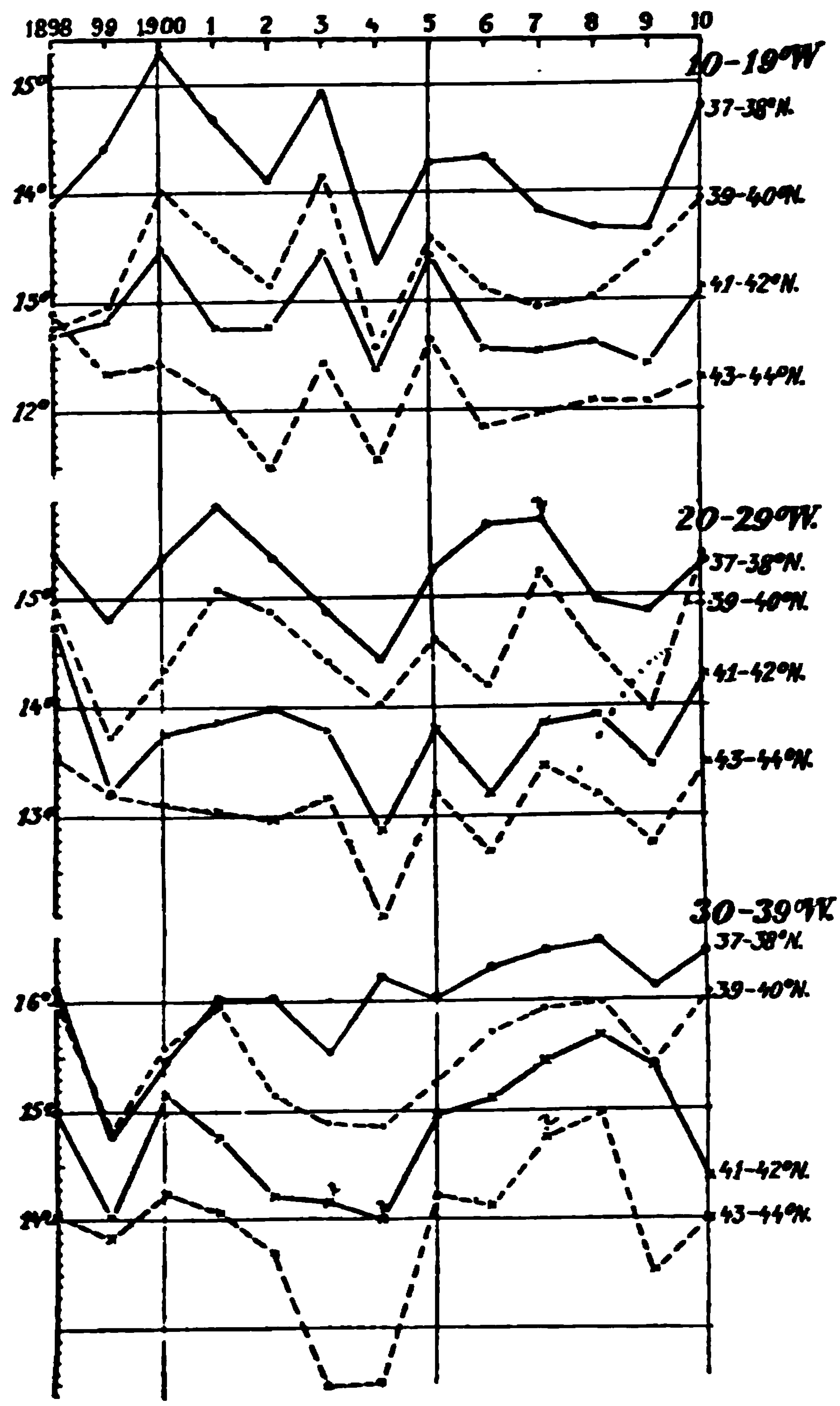

FIGURE 28. Curves for the surface temperature for 10° longitude fields between 10° and 40° west longitude and between 27° and 45° north latitude, February, 1898 to 1910.

and in the second decade group is strongly indicated, also the smaller minimum in the year 1899, particularly strongly indicated in the first decade group. Both the first and the second maximum periods are distinctly indicated. The difference between the western

and the eastern fields and the middle ocean region is also clearly marked.

In figure 27 we give to tenths of degrees the differences between temperatures in the first decade group, February, and the second decade group, March-April, for the same 4° longitude fields along the steamer route Channel-New York. The bold-faced figures indicate here increase of temperature from February to March-April, while the inclined ones indicate cooling. We see that here also a certain regularity or system prevails with regard to the place and time of the distribution of these temperature differences. We find for example that in the year 1903 the temperature diminished from February to March-April over great regions in the middle part of the ocean, while in the year 1904 there was an increase of temperature from February to March-April. In the year 1905 again there was a diminution of temperature during this time interval over the greater part of the fields. This also was the case in the year 1906 in the western half of the region, but not in the eastern half. In the first years, 1898 to 1900, there was in all fields a general rise of temperature from February toward March-April. This was also the case in the last year, 1910.

What we have said about the curves for the anomalies of the surface temperatures in our northern region Channel to New York is in general true of most of the corresponding values and curves in the southern region between 27° and 45° north latitude and between 10° and 40° west longitude. In consequence of the small number of observations we have, as already remarked, reduced the observations within this region to larger fields of 10° in length and 2° in width, and in this way twelve such 10° longitude fields were obtained (see fig. 1).

In figure 28 we show graphically by curves the values obtained for the surface temperature in all the years within these twelve fields. The variations of curves agree in all their principle features so well together that they must certainly be closely representative of the truth. It is moreover worth noting that the agreement between the curves is particularly good for those fields which adjoin one another in the direction north to south between the same 10° longitude intervals. The agreement is not so good for the fields taken from east to west. Finally there is a good agreement between the curves for these three groups of 10° fields and the curves of the next northerly or northeasterly lying 10° fields of the northern region of our observational material, that is, Channel to New York (see figs. 20 and 28).

If we consider now the different parts of this great region of investigation more closely, it is apparent that the difference in the geographical relations comes to an expression in these curves. Particularly the curves for those fields which adjoin the continental coast in the east, that is, between 10° and 20° west longitude, and those similarly lying on the west, that is, between 60° and 70° west longitude, differ from the curves for the fields in the middle of the ocean. This holds not only for the region Channel to New York (see fig. 20) but also for the southern region Portugal to Azores, figure 28.

The curves for the most easterly 2° fields of the northern region have in general about the same type, between 10° and 20° (see fig. 16) as is also shown by these 10° fields in figure 20. These curves are distinguished by several well marked features from the curve of more westerly fields. Particularly the curves for the first decade groups in figure 20 show as a distinguishing characteristic a symmetrical depression from the year 1898 to 1902, then two secondary maxima in the year 1903 and 1905 and a minimum in the year 1904. In the year 1906 there came a small depression. In the curves for the second decade group these characteristic features were somewhat altered.

A similarity with the curves for the first decade group is found also in the curve for the most northerly 10° field for the northern region, that is, from 10° to 19° west longitude and from 43° to 44° north latitude, as shown in figure 28. This is yet more apparent in the curve for the field westward of it, 20° to 29° west longitude and 43° to 44° north latitude.

All of these curves belong, as one may say, to the same type and are distinguished from the curves for the fields further out toward the middle of the ocean. Closely related to them are the curves for the three southerly 10° fields between 10° and 20° west longitude and between 27° and 43° north latitude as shown in figure 28, which also present different characters from the more westerly curves. Indeed their features are at times inverted.

The curves for the most westerly field of the ocean between 60° and 70° west longitude show great features which are completely different from those which we find in all the rest and they form a type completely distinct from them. In part they go inversely as the others. They have for example minima in the years 1901 and 1902 and in the year 1905. The curve for the first decade group has besides this a strong minimum in the year 1898. Furthermore they

have a maximum in the years 1903 and 1904, and particularly the curve for the second decade group shows a well marked maximum for the year 1903. For the later years after 1905 the curves show more similarity to the curve for the 10° longitude field to the eastward 50° to 59° west longitude and this, one might say, is to a certain extent a transition field, to the fields further east. These different types are shown distinctly in figures 21 and 22.

Turning now from the consideration of these dissimilarities which belong to the curves for the most western and most eastern region to the continents, and considering all the results from the whole

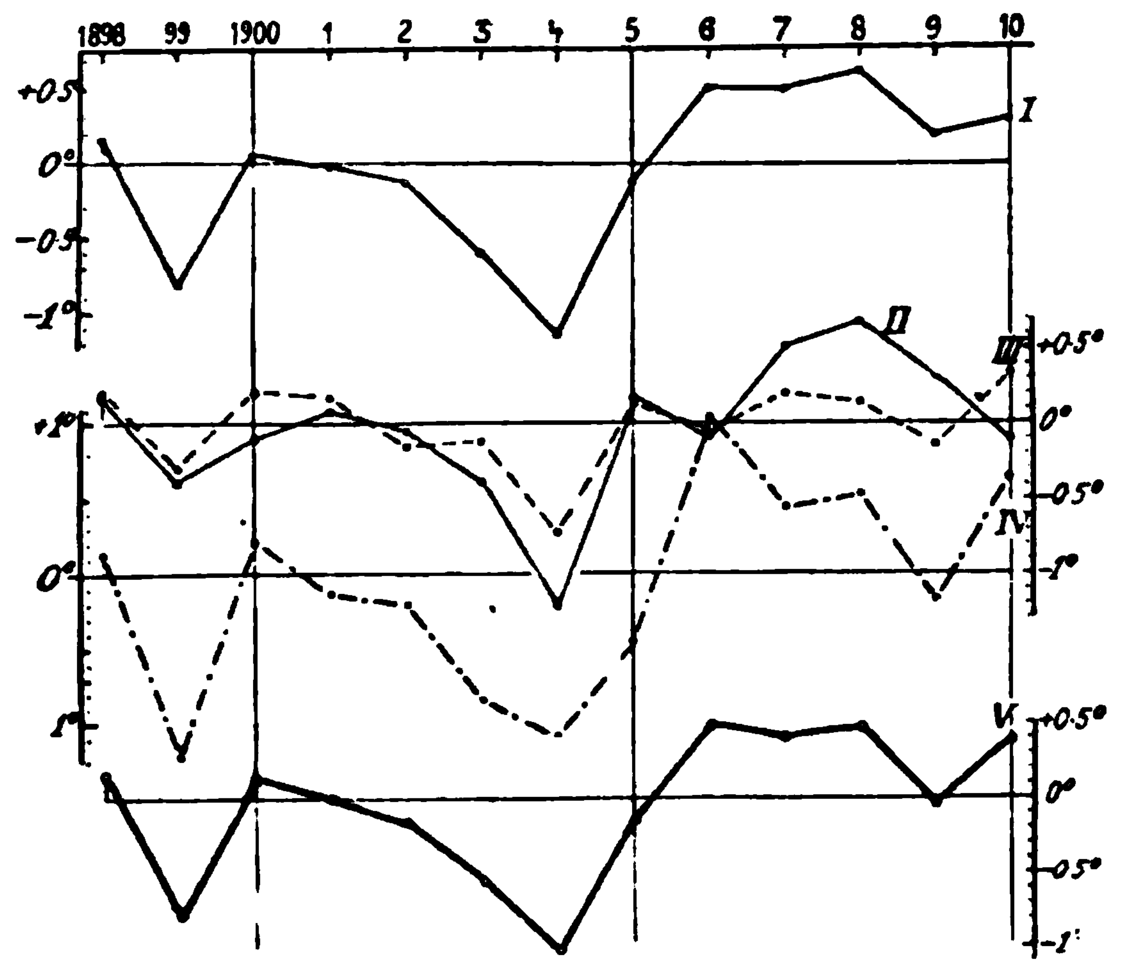

FIGURE 29. Curves for the anomalies of surface temperatures from February 3 to March 4.

I. Mean of all six 10° longitude fields, Channel to New York.
II. Mean of three most easterly 10° longitude fields, Channel to New York.
III. Mean of all twelve 10° longitude fields, Portugal to the Azores.
IV. Mean of three most westerly 10° longitude fields, Channel to New York.
V. Mean of the curves $\frac{II + III}{2}$ and IV.

assembly of fields within our investigated region as a whole, it is apparent that certain great features are common to the great majority of these curves. Hence we may conclude that if we should take the mean of the temperature anomalies for each decade group for each year for all the thousands of observations which we have collected within this region, the results would yield a curve which would exhibit the true condition for the whole North Atlantic Ocean.

We have found the mean of the anomalies for the average temperatures for each year and for each decade group for the six 10°

longitude fields between the Channel and New York. The results are given in table 2-W and shown graphically in the curve W, figure 48.

We have also assembled the values for both decade groups and obtained thereby yearly mean values of the temperature anomalies from all of our decades. This is also given in table 2-W and in the heavy curve of figure 48.

The corresponding average values for the first decade groups for the twelve southerly 10° fields are given in table 3-W, and in figure 29, curve III. The agreement between these different curves is excellent. If we take the mean of the values of the twelve southerly fields (see fig. 24, curve III) for the first decade and combine with it those for the three most easterly 10° fields, that is, between 10° and 40° west longitude (shown in figure 24, curve II of the northern region, Channel to New York), we obtain values which give the anomalies of the average temperature of this part of the ocean eastward of 40° west longitude in the first decade group. Again, if we take the mean values for each year between these results and the mean values for the three most westerly 10° longitude fields, that is, between 40° and 70° west longitude (shown in fig. 29, curve IV), we obtain thereby the average anomalies for this whole region of the Atlantic Ocean in its entire breadth. The values found in this way for the first decade group are given in the following table and graphically in the curve V in figure 29.

ANOMALIES OF MEAN TEMPERATURES[1]

	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–39° W. Northern Route	0.2	−0.4	−0.1	0.1	−0.0	−0.4	−1.2	0.2	−0.1	0.5	0.7	0.3	−0.1
10–39° W. 37–44° N.	0.2	−0.3	0.2	0.2	−0.1	−0.1	−0.7	0.1	−0.1	0.2	0.1	−0.1	0.3
Mean:	0.2	−0.3	0.1	0.1	−0.1	−0.2	−1.0	0.2	−0.1	0.4	0.4	0.1	0.1
40–69° W. Northern Route	0.1	−1.2	0.2	−0.1	−0.2	−0.8	−1.1	−0.4	1.0	0.4	0.5	−0.2	0.6
Mean of the two last lines	0.2	−0.8	0.1	0.0	−0.1	−0.5	−1.0	−0.1	0.5	0.4	0.5	−0.0	0.4

This treatment yields a curve very similar to the others which represent the variations of the su
Atlantic Ocean in the coldest par
gated period of thirteen years.

Characteristic features of these
A great depression in the years
in the year 1899, and two ma

[1] The values of the anomali
mals, although we have giv

1902 and 1906 to 1908. These features appear very distinctly in most of the curves compared both in figure 21 and in figure 22. In the latter maximum period 1906 to 1908, the temperature was on the whole considerably higher than in the earlier period of 1902, not only in February but also in March-April. This, however, was not the case for the average temperatures for the twelve southern fields (see fig. 29, curve III) where the temperature of the last maximum period was lower than that of the first maximum period of 1902. This was yet more marked in the most southeasterly fields between 10° and 20° west longitude and particularly between 37° and 39° north latitude, as shown in figure 28. A similar depression of temperature from the first to the last maximum period finds representation in the curves for the 10° longitude fields of the Danish observations northerly of 50° north latitude between 20° and 40° west longitude (see figs. 31 and 32).

As already remarked, the results for the regions of the sea nearest to the continental coasts on both sides of the ocean indicate that the continents influence the variations of the surface temperatures of those regions of the ocean adjacent to them. It may therefore be better to omit all these fields between 10° and 20° west longitude and between 60° and 70° west longitude in determining the mean value of the variations from year to year of the surface temperatures of the coldest part of the year representative of the Northern Atlantic Ocean.

Table 2-W gives the anomalies for the average temperatures which we obtain in this way for the four middle 10° fields between 20° and 60° west longitude of the northern region. These are given for both decade groups separately as well as combined, and are represented in figure 49 in the curves marked W.

Table 3-W, as well as curve S in figure 30, give the anomalies of the average temperatures for February for the eight 10° fields between 20° and 40° west longitude of the southern region.

The upper full curve N of figure 30 represents the anomalies of the average temperatures for February for the four 10° fields between 20° and 60° west longitude of the stretch of the ocean from the Channel to New York, while the dotted curve gives the corresponding temperatures for the two 10° longitude fields between 20° and 40° of west longitude, which therefore correspond in longitude to the eight southerly fields whose temperature anomalies are shown in curve S. We notice that the agreement between the curves for these southerly fields and for the northerly fields is extraordinarily close.

We may therefore reasonably assume that these curves are typical representations of the real temperature variations of the ocean surface of the Middle Atlantic Ocean for the period which we have investigated. We may also assume that the great and characteristic features of these deviations are common to the whole ocean surface.

The results do not support the conclusion of Petersen that the variations in the surface temperatures for the different months of the year in the eastern and western parts of the Atlantic Ocean tend to go in opposite directions with respect to an axis at 40° west longitude. Referring to curves II and III for the ocean eastward of 40° west longitude and curve IV of the ocean west of

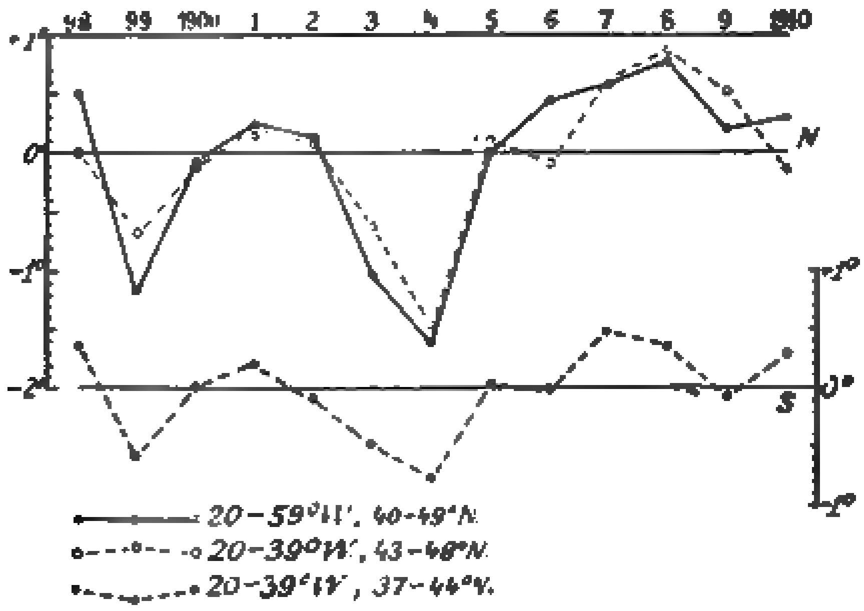

FIGURE 30. Curves of the anomalies of the surface temperatures fo February 3 to March 4.

40° west longitude in figure 29, we see that the principal features of these curves are the same. As shown in figure 40 we find only in isolated years, as February, 1905, and March-April, 1899, such an opposition of temperatures as Petersen assumes.

If we now consider the observed variations in the surface temperatures in the 10° longitude fields for the Danish observations northerly of 50° north latitude,
of the ocean between 20° and
features in the variations for]
This result is shown by our curv
30° and 39° west longitude in
compared for example with t
30 and 48-W. A gr
curves for the ye

In the year 1901 the temperatures were lower than in the years 1900 and 1902, a condition which we find duplicated in the average curves for the fields further southward as shown in figure 48. A rather poor agreement is found in the latter parts of the curves where the anomalies for the time interval between 1905 and 1907 seem to be on the whole very much less than they are in the fields further south.

In March-April, 1898, the temperature was fairly low. This does not correspond to the conditions of the ocean surface temperatures in the fields further southward. However we find that the air temperature for March-April in these southern fields averaged distinctly low in the year 1898 (see fig. 49). Most of the curves

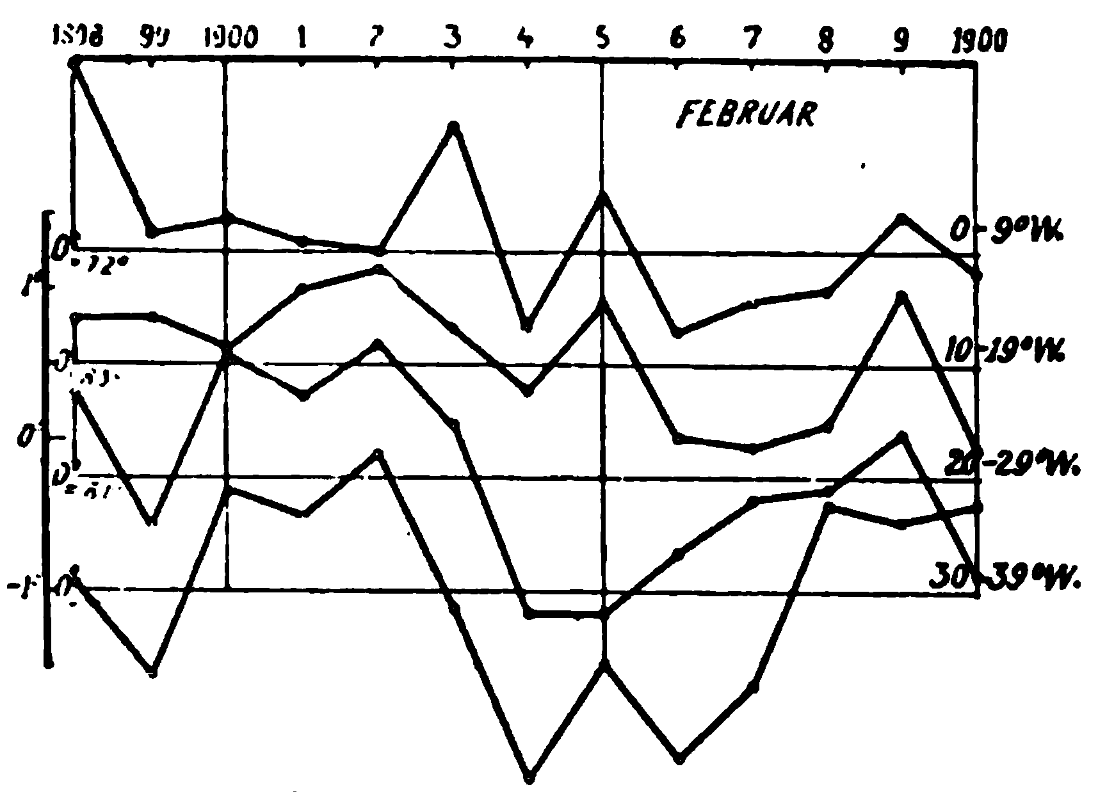

FIGURE 31.

for March-April show in the years 1903, 1904, and 1905 a great depression. In the later years 1905 to 1907 and 1908 the temperature in the northerly Danish fields was decidedly low. This is shown by the curves in figure 32.

The temperature curves for the two most easterly 10° longitude fields of the Danish observational region show totally different characteristics as well for February as also for March-April from the above mentioned curves. In particular in March-April they go inversely and are closely related with the curves of the most easterly 10° longitude fields farther south, 10° to 19° west longitude in the region of the Channel to New York, and particularly with the 10° to 19° west longitude region between Portugal and the Azores. It appears therefore as if this difference between the variations of temperature in the most easterly part of the North Atlantic and the variations in the fields further out in the ocean is charac-

teristic of the whole stretch from 37° north to 60° north. The curves for the fields 10° to 19° west longitude take transition forms between the curves for the field 0° to 19° west longitude and those of the more westerly region.

VARIATIONS OF THE SURFACE TEMPERATURES FOR THE COLDEST PARTS OF THE YEAR COMPARED WITH THE VARIATIONS OF THE YEARLY TEMPERATURES IN DIFFERENT PARTS OF THE SEA

If, as we have already remarked, the surface temperature in the North Atlantic Ocean during the coldest parts of the winter and towards the end of it may be assumed for provisional purposes to

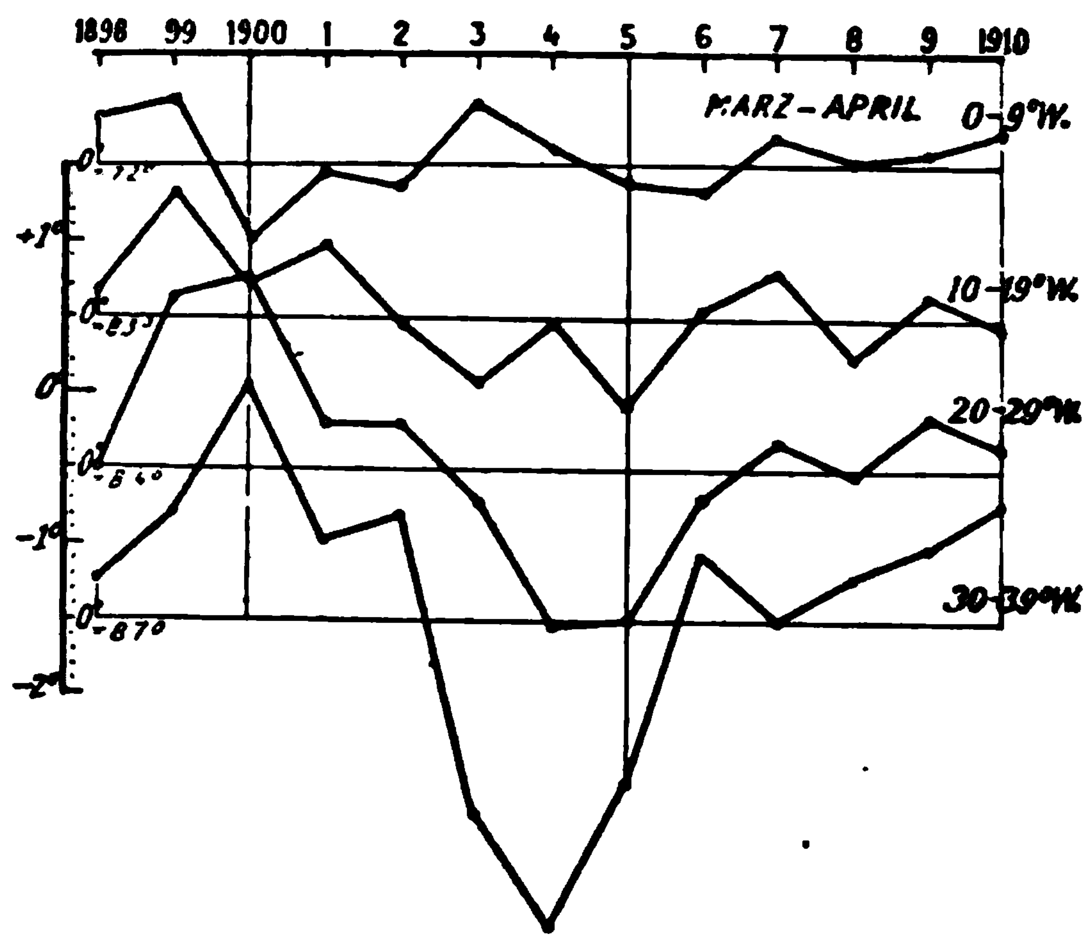

FIGURE 32.

FIGURES 31 and 32. Curves for the surface temperatures of the 10° longitude fields of the Danish observations north of 50° north latitude between 0° and 10° west longitude and 58° and 60° north latitude, between 10° and 20° west longitude and 56° and 60° north latitude, between 20° and 30° west longitude and 53° and 58° north latitude, between 30° and 40° west longitude and 58° and 54° north latitude, for February (fig. 31) and for March 16 to April 15 (fig. 32).

be closely the same as that of the underlying masses of water to considerable depths below, we may draw the following conclusions: The variations in the surface temperatures during the coldest season of the year are not merely superficial and accidental deviations in a thin surface layer, but in part, at least, indicate deep seated changes in the temperature of the upper water-masses of the ocean. These changes must certainly continue through a long time interval and not simply in the brief intervals embraced in our observations.

Our curves then show not merely the variations during the two months of our period of investigation from the beginning of February to the middle of April, but also certain great features which remained for a long period unchanged.

It is therefore not improbable that at least the principal features of these variations occur in the average yearly temperatures for the surface in our fields, although of course in the yearly curves the variations would be smaller and more smoothed out.

We have had no opportunity to collect the observational material required to investigate this matter. The above mentioned Danish observations north of 50° north latitude and those of Petersen and

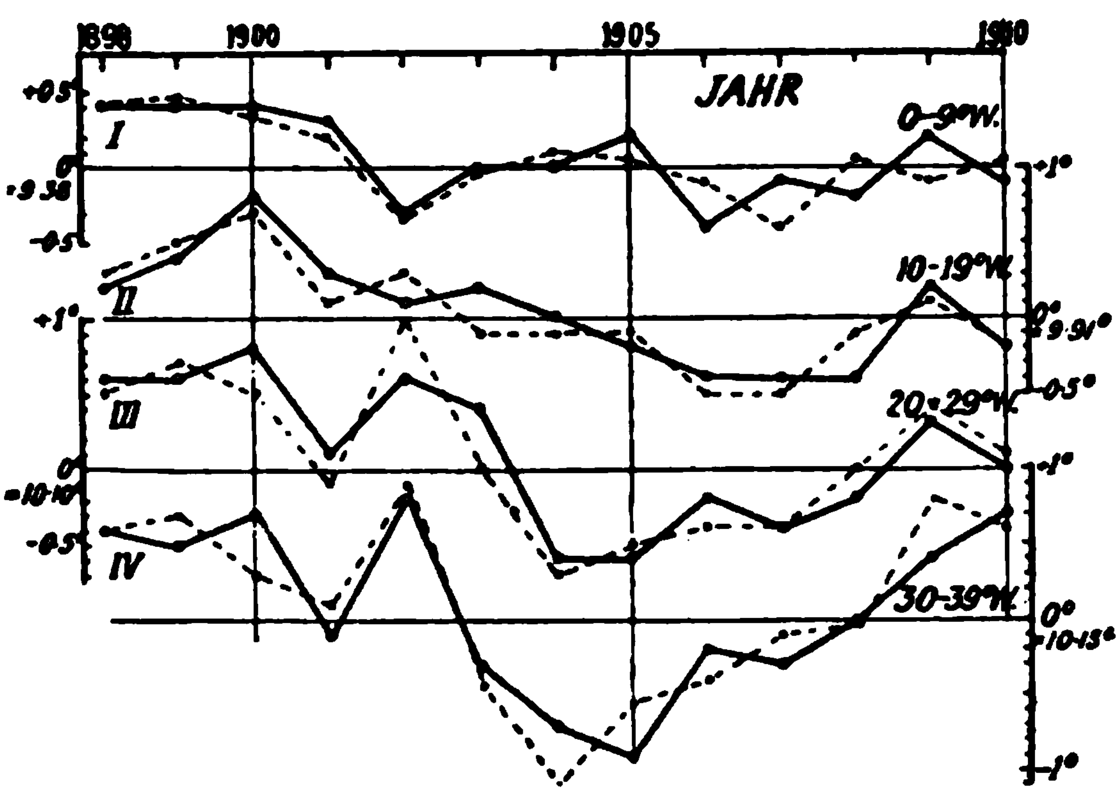

FIGURE 33. Curves for the yearly means of temperature anomalies in the four 10° longitude fields of the Danish observations (see figs. 31 and 32). Full-drawn curves indicate the mean of the years running from September to August, the dotted curves the mean of the calendar years.

Liepe furnish, however, a means of studying the question somewhat more closely.

In figure 33, curves I to IV give a representation of the yearly mean for the four above-mentioned Danish fields. The full drawn line shows the mean for the twelve months from the 1st of September of the previous year to the end of August of the given year, while the dotted curves show the mean values for each calendar year. If one compares these curves with the curves for February and March-April (see figs. 31 and 32) an unmistakable similarity between the characters of the single curves is seen. The similarity is even better than the incompleteness of the material would lead one to expect. It is also clear that a thorough and analogous dissimilarity exists between the types of curves for the eastward and the two western fields.

The opposition between the most eastern field, 0° to 9° west longitude, and the most western fields, 20° to 29° and 30° to 39° west longitude, is sharply indicated in the curves of figure 33, numbers I, III and IV. Curve II for the middle field 10° to 19° west longitude shows a transition form.

The agreement between the yearly curves and the February and March-April curves is distinctly indicated by taking the mean for all four fields for February and March-April and also for the years and comparing them as is shown in figure 34. The curve of mean values for February and March-April combined, which is drawn as a full line in the figure, shows particularly well the close parallelism with the curve for the year (September-August).

Figure 35 shows the variations of the yearly temperature (September-August) for Petersen's 1° fields. We note that the curves

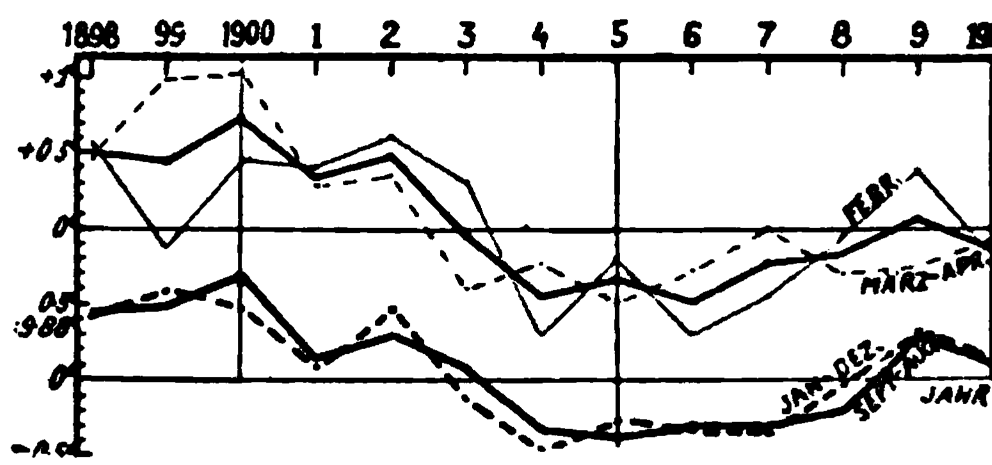

FIGURE 34. Curves of the temperature mean for all four Danish fields (compare figs. 31 to 33) for February, March-April (upper lines) and for the whole year (lower lines).

for the station No. 1 and westward to No. 7 show considerable similarity each to each and form so to speak a certain type, which however, gradually changes from the east toward the west. This imparts to these curves an impression of trustworthiness. The curves for the stations westward of station 8 have little or no similarity each to each and this is very likely due in the greater part to the accidental errors of the observational material.

On the whole there is a certain similarity apparent between the yearly curves for Petersen's stations 1 to 6 and the yearly curves for the Danish fields in corresponding longitudes (see fig. 33). The reader may compare figure 35, station 1, with figure 33 I, figure 35, stations 3 and 4, with figure 33 III, or figure 35, stations 5, 6, 7, with figure 33 IV.

There prevails also a strongly marked similarity between the yearly curves for Petersen's most easterly station, the curve for February for the same station (see fig. 36, P St. I) and our curves

for February and March-April for the corresponding most easterly fields as shown in figure 36. We have taken the yearly value for 1903 from Petersen's own drawing (1912). The correspondence between the yearly curve and the curve for February and March for Petersen's station No. 1 is obviously not so good as the agreement between these yearly curves and the February curve for our most easterly fields between 10° and 14° west longitude. See also the curve for the field between 10° and 20° west longitude, shown

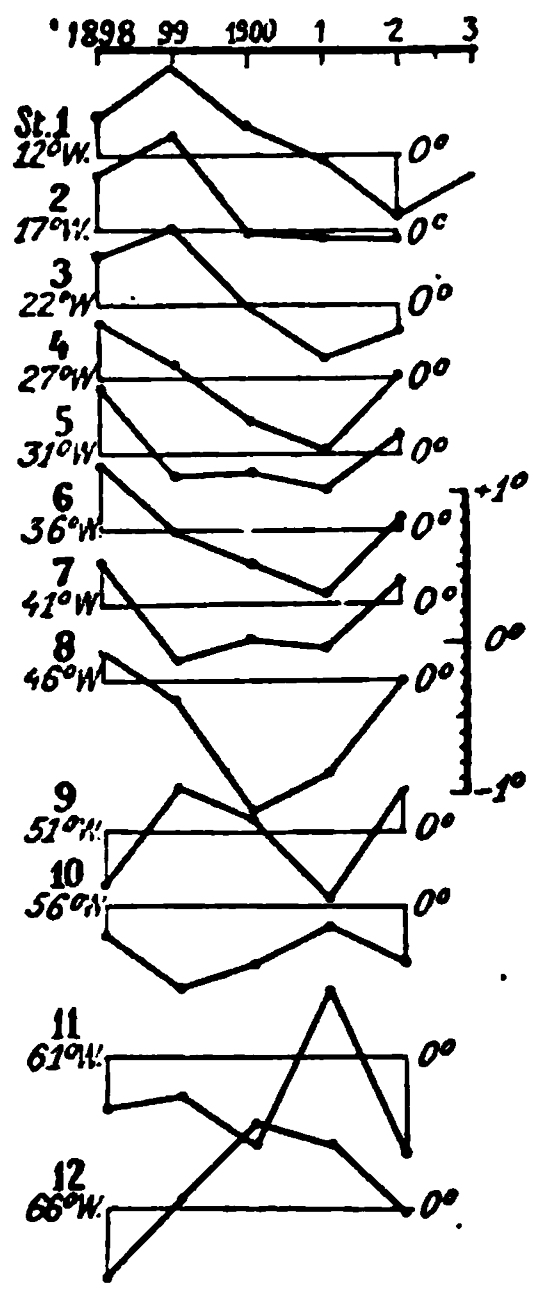

FIGURE 35. Petersen's stations I to XII along the shipping course Channel to New York between 11° and 60° west longitude. Curves for the yearly anomalies of the surface temperatures computed from September 1 of the previous year to August 31 of the given year.

in figure 20, 10° to 19° west, and see also the fields south of it between 10° and 20° west longitude, 43° and 44° north latitude shown in figure 36, 10° to 19° west. The reason for this we attribute to the fact that our curves, which are determined from much more extensive observational material, are more trustworthy than the monthly curves for Petersen's station No. 1.

It is noticeable that the yearly curve for Petersen's most westerly station, that is to say, No. 12 at 66° west longitude between 40° and 41° north latitude, showing as it does a maximum in the year

1900, an absolute minimum in the year 1898, as well as low temperature in the year 1902, exhibits great similarity with our February curve for the most westerly 10° field at 60° to 69° west longitude, as shown in figure 20, 60 to 69° W. Petersen's most westerly yearly curve has also similarity with the February and March curve for his station No. 12 and also with the February and March curve for the mean value of his two most westerly stations, stations 11 and 12, as shown in figure 13, 11 and 12.

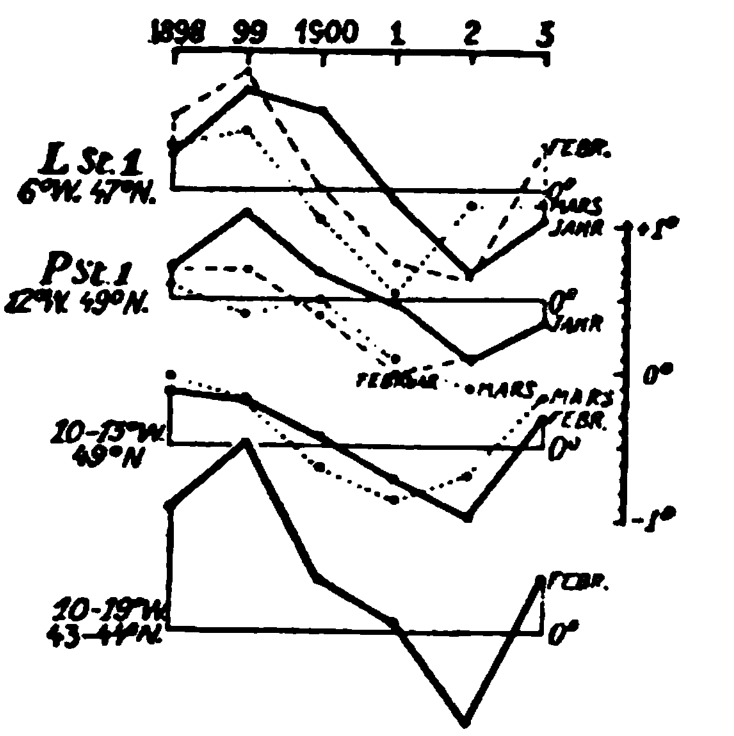

FIGURE 36. Curves for the anomalies of the surface temperature. L. St. I for Liepe's station, I for the year (September to August) and for February to March. P. St. I for Petersen's station I for the year (September to August) and for February and March, 10° to 13° W., for the two 2° fields between 10° and 14° west longitude and between 49° and 50° north latitude, of our northerly course Channel to New York, 10° to 19° W. for the most northeasterly 10° longitude field between 10° and 20° west longitude, 43° and 45° north latitude of the course Portugal to the Azores.

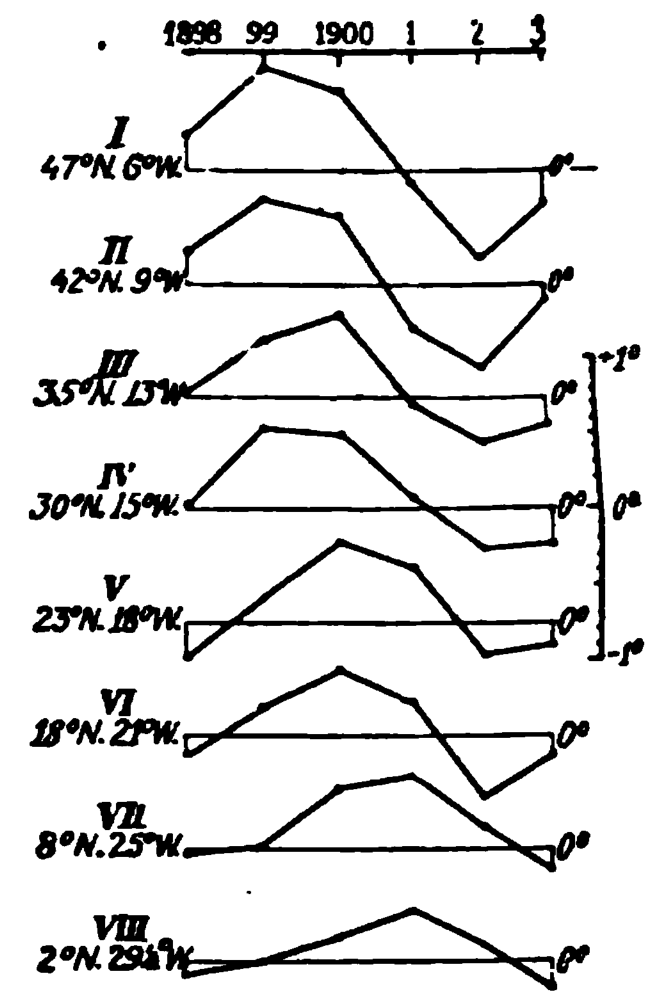

FIGURE 37. Liepe's stations I to VIII. Curves for the anomalies of the yearly temperatures computed from September 1 of the previous year to August 31 of the given year.

The mean value for all of Petersen's stations for February shows similar variations with the corresponding mean value for all of our fields between the English Channel and New York (see fig. 29, I).

Since Liepe's stations lie along the east side of the Atlantic Ocean where the distance between the isotherms is great, one would expect that the yearly curves would exhibit a good correspondence with the February and March curves for these stations. This expectation is realized for the most part of the cases. In figure 37

we have given the curves for September and August of Liepe's different stations. It is apparent that there is a great degree of similarity between the curves each to each. They show a gradual change from the north toward the south which indicates that they actually represent the conditions fairly well. There is a good similarity between the yearly curve for Liepe's station 1, his February curve for the same station, the yearly curve for Petersen's station 1 and the February curve for our most easterly field as shown in figure 36.

The similarity between the yearly curve for Liepe's station 3, his February and March curves at the same station at 35° north latitude and 13° west longitude, and our February curve for the corresponding field which is a little further north between 37° and 38° north latitude, and between 10° and 20° west longitude is also very good, as shown in figure 38.

The yearly curve for Liepe's station 2, at 42° north latitude 9° west longitude, shown in figure 37, shows less similarity with the February and March curves for the same station (see fig. 15), but the February curve for the nearest of our fields, see figure 28 and figure 1, is more similar. Liepe's station 2 lies so near the coast that the surface temperature of it is influenced by this proximity. The agreement between the yearly curves and particularly the March curves for stations 4 and 5 and the February curves for stations 6, 7, and 8 is also very good.

SIMILARITY OF THE TEMPERATURE VARIATIONS OVER GREAT REGIONS OF THE OCEAN. DIFFERENCE BETWEEN EASTERLY AND MIDDLE PARTS OF THE NORTH ATLANTIC OCEAN

The yearly curves for Liepe's stations, for Petersen's easterly stations, and for the most easterly Danish fields are very similar to one another for the short time interval here examined, 1898 to 1903. Liepe has published in his treatise of 1911 the curves for all the stations for the whole time 1883 to 1903. They show also for the years before 1898 a great similarity each to each. We may therefore draw the conclusion that the variations in the yearly temperatures over the whole eastern part of the North Atlantic Ocean from 60° north latitude to 30° north latitude (Liepe's station 4) or even down to 18° north latitude (Liepe's station 6, fig. 37) are in their principal features about the same. This is also confirmed by the twelve-monthly consecutively smoothed temperature curves for different stations which we shall refer to later (see fig. 56).

For this easterly part of the ocean we have furthermore found that the temperature variations of the coldest seasons of the year, February and March, are very similar to the variations of the yearly means themselves. This holds as we have said above, (see figs. 33 and 34) for the easterly Danish fields. We believe that we may safely assume that this is a general rule for the North Atlantic Ocean.

If we return again to Liepe's most southerly stations, we find some relations of considerable interest. The yearly curves for his stations 7 and 8, at 8° and 2° north latitude, which lie midway of the Atlantic Ocean between Africa and South America have a certain similarity with those for his more northerly stations, but the maximum is displaced to the year 1901, whereas in the trade wind region it fell in the year 1900, and still further north, even in the year

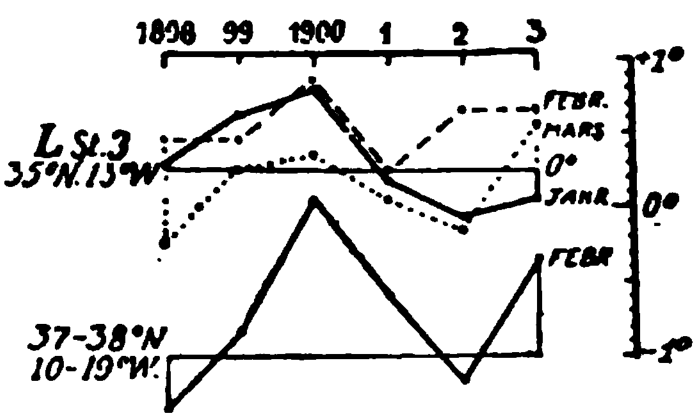

FIGURE 38. Curves for the anomalies of the surface temperatures for Liepe's station 3 (L. St. 3) for the year (September 1 to August 31) for February and March as well as for our fields between 37° and 39° north latitude and 10° and 20° west latitude for February.

1899. It is surprising that the similarity goes so far when one considers that Liepe's stations 7 and 8 lie in aonther ocean current. Station 7 lies, at least in the northern summer, in the equatorial counter stream where this current in August and September, under the influence of the southwest monsoon, reaches its greatest development. On the other hand, in the time interval from December to May the station is penetrated by the northerly equatorial current which reaches its strongest development in March. The station 8 lies in 2° to 3° north latitude, 29½° to 30½° west longitude, within the region of the south equatorial stream. Only from February to the middle of April does this current often show itself southerly of 3° north latitude and it reaches its most considerable intensity in July.

Yearly curves for these two tropical stations show nevertheless a special type and have as we have said much similarity with the February curves for the same stations (see fig. 15). They have

also a certain similarity with the February curves especially in our 10° longitude fields between 20° and 50° west longitude, shown in figures 20 and 30, where we find the maximum in the year 1901 at a temperature sinking gradually from this time on toward 1903. However, the tropical curves show no minimum in the year 1899, although there seems to be a tendency in both curves towards a

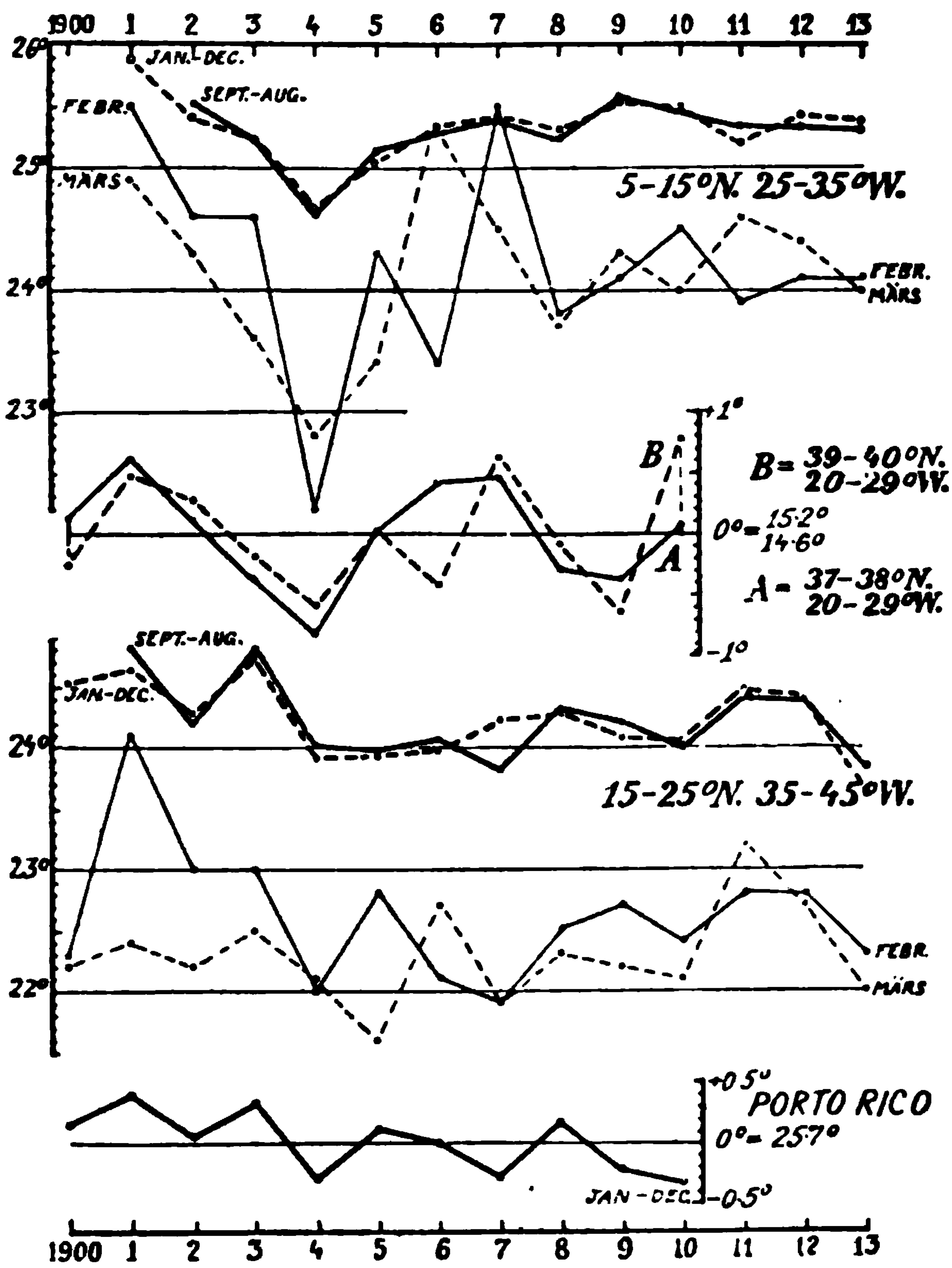

FIGURE 39. Curves for the surface temperatures (in the year and in February and March), for the Dutch 10° squares from 5° to 15° north and from 15° to 25° north. The temperature anomalies for our fields A and B and the air temperature for the year at San Juan (Porto Rico).

lower temperature in this year. This comes most strongly to view in the curves for February, and the March curves have minima in the year 1899. It may be remarked as we have earlier said that Liepe's two tropical stations, 7 and 8, are near the middle of the Atlantic Ocean, as are also our fields between 20° and 50° west longitude and between 37° and 50° north latitude. The distance

between these two stations and our fields is, however, very great, and from the station 7 it is over 3,100 kilometers to our most southerly fields, or about as much as from the Channel to Newfoundland (see pl. 15, fields VII, VIII, 3-5, 7-14; see also fig. 56).

It is of great interest to compare the results with the observations in the 10° square fields between 5° and 15° north latitude and 25° and 35° west longitude, shown in plate 15, field 20 as given for the years 1900-1913 in the Dutch "Monthly Meteorological Data for 10° Squares in the Atlantic and Indian Oceans" (Koninklijk Niederlandsch Meteorologisch Instituut, No. 107-a Utrecht 1914). In general the fields of 10° square are too large to show the true conditions by merely taking mean values of all observations within these fields without reference to their local situation. Moreover the observational material itself within these great fields is in most of the fields too meagre to give satisfactory values. In the 10° square field which we have referred to the number of observations in most months is about 10 per month but varying between 5 and 30, sometimes more. We must on this account look for some irregularities in the mean values for the different months. We have computed the mean yearly temperatures for this field, both for the calendar year January to December and for the twelve months September to August. The values obtained are graphically given in the topmost curve of figure 39. The heavy full drawn line is the yearly curve for September to August and the heavy dotted line, the curve for the calendar year. We have also given the curves of the February temperature (weak full drawn lines) as well as of the March temperature (weak dotted lines) for the same field. Under these curves we have drawn the curves B and A. These relate to our two most southerly fields of corresponding longitudes between 20° and 30° west longitude, which are about 2500 kilometers further north (see pl. 15, fields 13 and 14). The curves are for February. One must admit that between these curves and the February and March curves for the tropical field there exist with certain exceptions a very great similarity. It is apparent that the variations in the tropical fields are much greater than in our fields further north.

The two yearly curves for the tropical field have a characteristic

21 and 22. There is, however, this notable difference that the tropical yearly curves reach an absolute maximum in the year 1901 which exceeds that attained in the later maximum period between 1907 and 1909, whereas our more northerly curves, Channel to New York, figure 20, 30N give their highest values in this later maximum period as we have already said. The curves for our more southerly field between 10° and 30° west (see figs. 28 and 39A and B), particularly for the most southeasterly fields, are similar to the tropical curves in this respect. It appears as if in these years a depression of temperature occurred in the southeast, but the strong minimum in the year 1904 is found in all curves alike.

We may add that the curves for February and March for the tropical field have a certain similarity with the February and March curve for the 10° field 30° to 39° west longitude of the Danish observations between 50° and 54° north latitude. Compare for instance figure 39 with figures 31 and 32. The February curves for both fields show the same depression in 1904, a rise in 1905 and again a depression in 1906, but there is a dissimilarity in 1907 as also in 1902. The March curves show the same great depression in 1903, 1904, 1905, a rise in 1906, depression in 1907, but a dissimilarity in 1908.[1] All this points to a dependence and congruence in the variations over great stretches of the Middle Atlantic Ocean, similar to those which we have already called attention to in the more eastern region. This dependence is perhaps more clearly shown by comparison of the twelve-monthly consecutively smoothed temperature curves for the middle stations of Petersen between 22° and 47° west longitude, shown in figure 56, and the western Danish stations (see fig. 55), the tropical stations of Liepe (see fig. 56), and others to which we shall later refer.

Of the three other 10° squares treated in the Dutch report only the most northwesterly field between 15° and 25° west longitude, shown in plate 15, field 19, contains throughout a sufficient number of observations to warrant the discussion of it. For this field we have computed the yearly means as before, and we give both curves in figure 39. Of these the full heavy curve indicates the yearly mean for the 12 months, September to August, and the heavy dotted curve the yearly mean for the calendar year. In this figure we give for the same field also the February curve in weak

[1] The February curve for the Dutch field 15° to 25° north, 35° to 45° west, shows a depression in 1907 (see fig. 39) and in this year more similarity with the curve of figure 32.

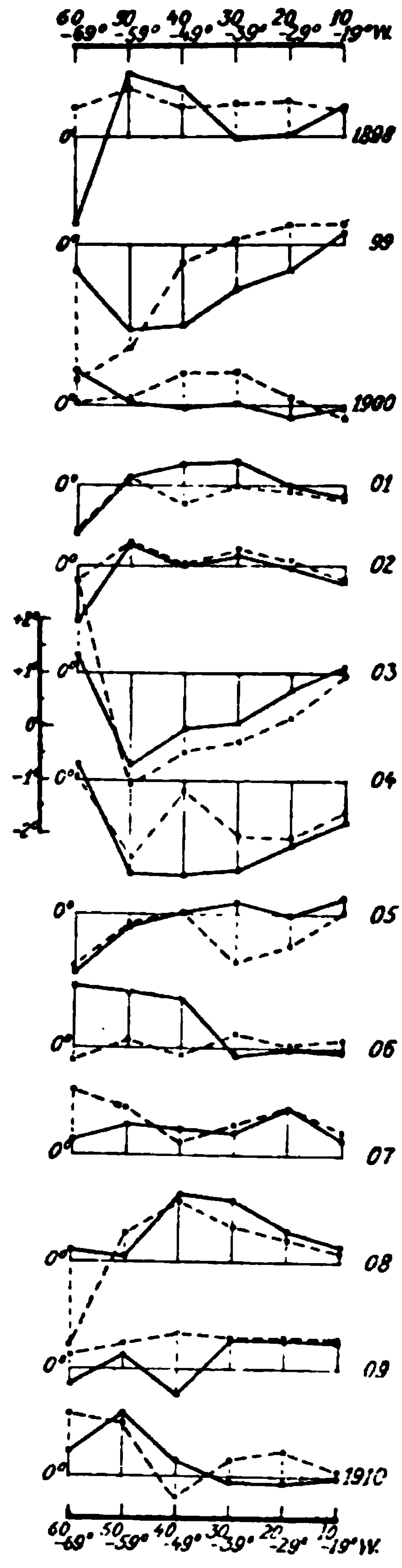

FIGURE 40. The anomalies for the surface temperatures for February and March-April for the 10° longitude fields along the route Channel to New York for each year.

full drawn lines and the March curve in a weak dotted line. These curves have on the whole considerable less similarity with ours though the February curve for the years 1900 to 1905 has the same great features as shown in our curves. The curves for these Dutch fields show on the whole after the year 1904 uncommonly low temperatures.

The lowest curve of figure 39 gives the yearly temperatures of the air in San Juan, Porto Rico. Between this curve and the yearly curve September to August for the Dutch field 15° to 25° north latitude and 35° to 45° west longitude there exists clear similarity, though with some exceptions, particularly in the year 1905. But in this year the February curve for the same field shows a rise similar to that which we found in several other curves. The curve for Porto Rico shows in a still more marked degree the tendency to sink from 1901 to 1910.

DIFFERENCE OF TEMPERATURE VARIATIONS IN THE WESTERN, MIDDLE, AND EASTERN PARTS OF THE NORTH ATLANTIC

If we consider the run of the temperature anomalies in the different 10° fields from west towards east in the course of the period of observation, we find on the whole a great regularity. Figure 40 gives an assembly of the yearly curves for the temperature anomalies of the surface water for both decade groups for the whole ocean stretch from the Channel to New York. The same curves for the different years are also given in plates 16 to 40, which also include the corresponding curves for the more southerly region between Portugal and New York shown on the left. The minimum years 1899, 1903, and 1904 give curves with well marked concavity (see fig. 40) whereas the maximum years, for example 1901 and 1908, show convex curves. This holds particularly for the month of February. This circumstance finds its natural explanation in the fact that the yearly variations in the middle part of the ocean are relatively much greater than those of the more eastern part. There happens, in other words, in minimum years a rise of the curves towards the eastern fields, starting from the middle fields. If we take the difference between the anomalies for one of the middle fields and the most easterly fields, we find therefore a negative value in the minimum years and a positive one in the maximum years. For the month of February we have obtained the anomalies of such differences of the surface temperatures for one of the fields 30° to 39° west longitude minus the surface tem-

perature for the corresponding field 10° to 19° west longitude for the steamer route Channel to New York, and also for the region Portugal to Azores. The result of this computation is seen in figure 41 which gives well marked minima in the cold years 1899 and 1903, and maxima in the warmer years, 1901 and 1908. The year 1904 shows no minimum for the Azores field, because in this year it was cold both in the east and in the west, but along the steamer route Channel to New York it was on the other hand considerably colder in the western regions that in the eastern ones and hence the anomaly difference which we have been speaking of is negative and rather great for this more northerly region.

If one compares these differences in temperature of the Atlantic Ocean in the middle (30° to 39° west longitude) and the east side (10° to 19° west longitude) with the February temperatures at

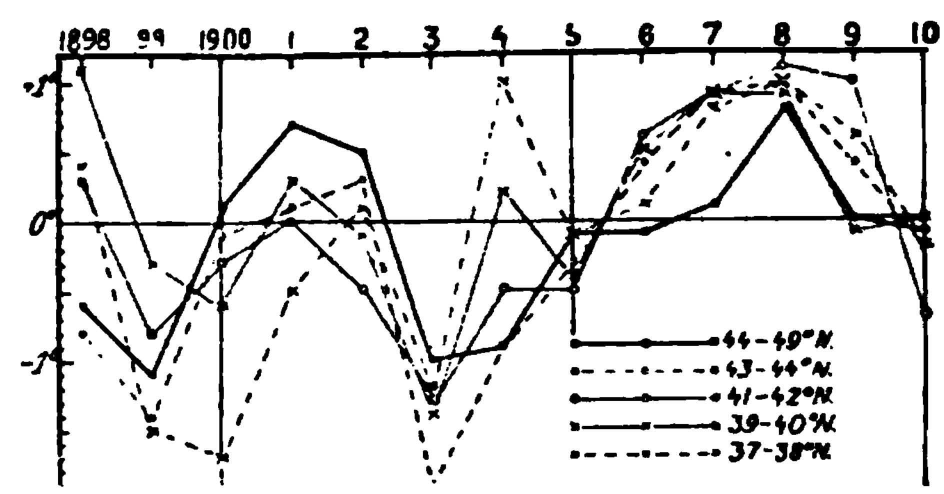

FIGURE 41. Curves for the difference between the temperature anomalies for one of the fields 30° to 39° west longitude and one of the most easterly fields 10° to 19° west longitude along the route Channel to New York (curve 44° to 49° N.) and in the region Portugal to the Azores (the four other curves).

Liepe's station 1, he finds the peculiarity that the temperature at Liepe's station 1 is high when the difference is small or negative, and vice versa. In figure 42 we give the average curves for the above mentioned differences. The full drawn curve shows the mean of the four southerly station curves of figure 41 and the dotted curve gives the mean of all five curves of figure 41. Under these curves is given in the same figure the February curve for Liepe's station 1 with the scale of temperatures inverted. We see that the agreement between this curve and the above mentioned mean curves is very striking. The yearly temperature curve for Liepe's station 1 (from September to the end of August) is also shown in the same figure. Since this yearly curve, as we have said, has great similarity to the February curve, we should also expect a certain agreement with the difference curve.

In the same figure is given a curve for the temperatures of the air for February in Hamburg (according to Thraen, 1915). The scale is here also inverted. The agreement between this curve and the February curve for Liepe's station 1 and also for the curves

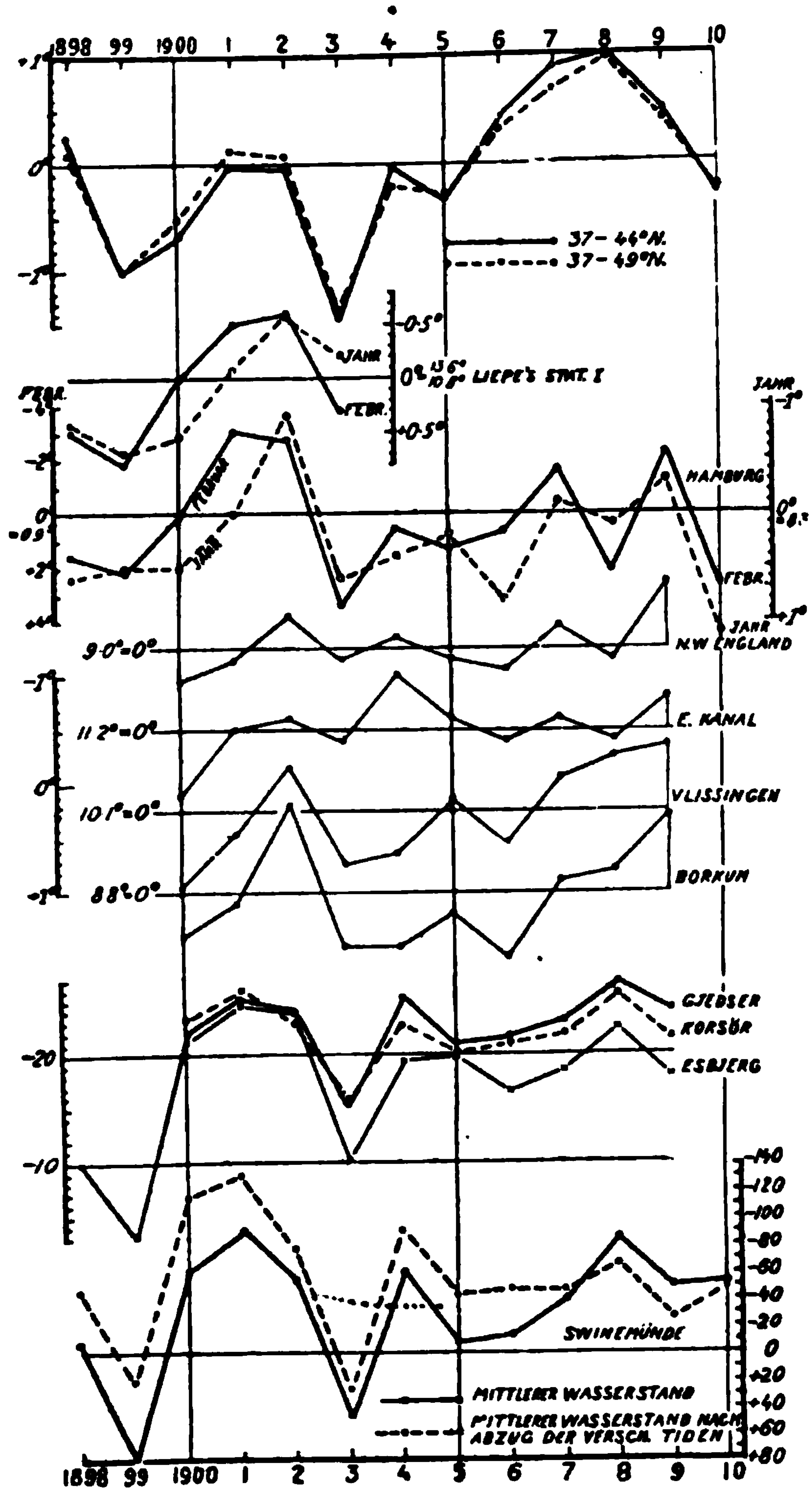

FIGURE 42. Curves for: Average difference between the temperature anomalies of the fields 30° to 39° west longitude and the fields 10° to 19° west longitude (the upper curves are the means of the curves of figure 41) for February; anomalies of the surface temperatures for February and for the year (September to August) at Liepe's station 1; anomalies of the air temperature for February and the calendar year in Hamburg; anomalies of the air temperature for the calendar year in northwest England, on the English Channel, in Vliessingen, and Borkum; water level for the calendar year in Gjedser, Korsor, Esbjerg, and Swinemunde. For the temperature curves and the water level curves the scales are inverted.

of difference between the surface temperature of the Atlantic Ocean in its middle part and its east side is on the whole very good. The principal exception occurs in the year 1908 when the February temperature in Hamburg shows a rise instead of a fall, while the difference between the temperature of the Atlantic Ocean has a maximum. Apart from this the run of the variations of

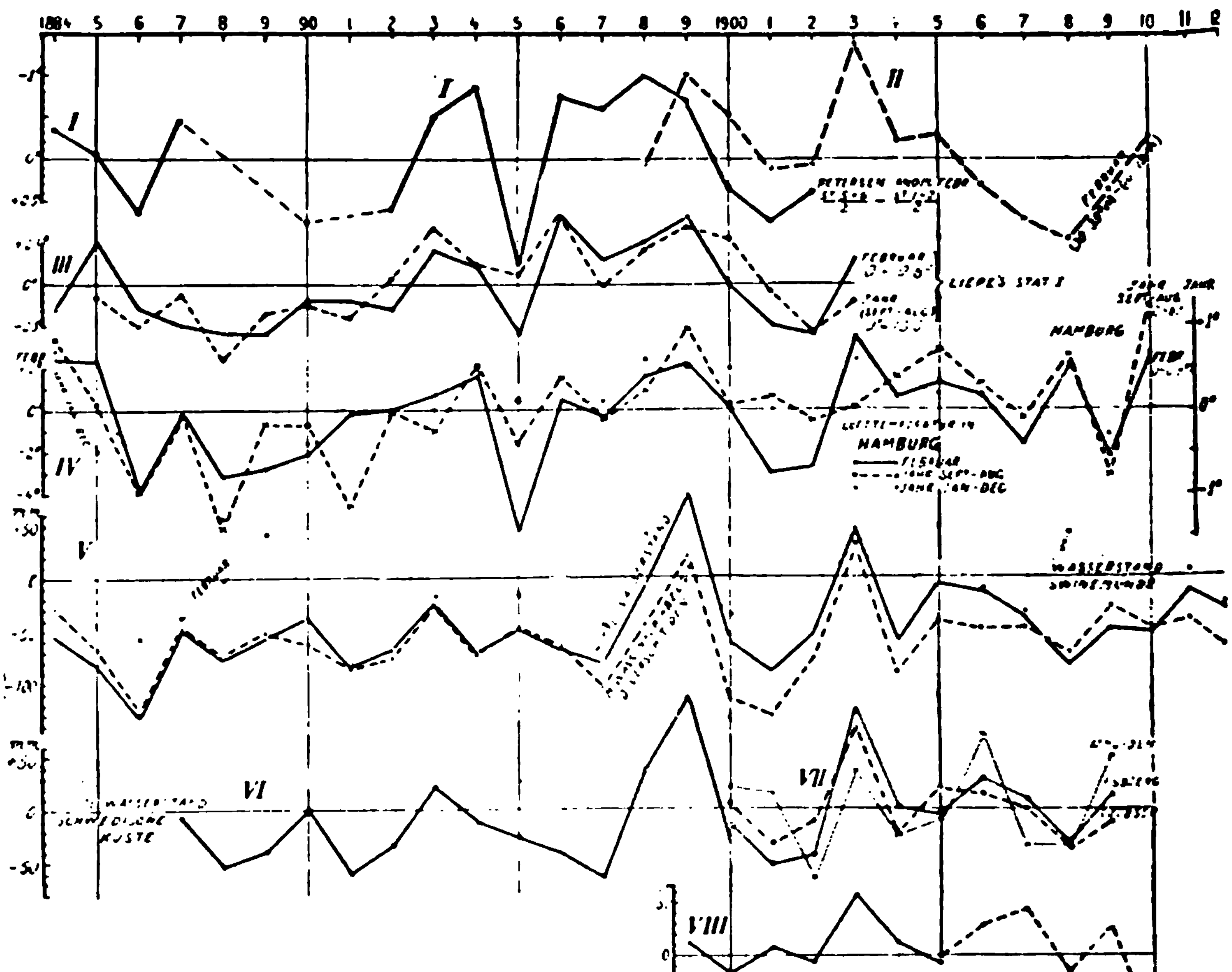

FIGURE 43. Curves: I: Difference between the temperature anomalies for Petersen's stations 5 and 6 and the temperature anomalies of his stations 1 and 2 for February. II: Corresponding differences between our fields 30° to 39° west longitude and 10° to 19° west longitude. III: Anomalies of the surface temperature in February and the year (September to August) at Liepe's station 1. IV: Anomalies of the air temperature in Hamburg for February, for the year September to August, and for calendar year. V: Average water level in Swinemunde for the calendar year and for February. VI: Average water level for the calendar year on the Swedish coast. VII: Average water level for the calendar year in Ijmuiden, Esbjerg, and Gjedser. VIII: Average water level for the calendar year in Stavanger and Narvik.

these curves is in complete agreement. Since the variati
the air temperature in a single month is naturally
than the variations in the surface tem
scale of the February curv
large as the others, as s

In this figure are also given the yearly temperatures in Hamburg for the interval September to August as a dotted curve and in figure 43 for January to December as a dotted curve, the scale being indicated at the right. As we should expect, the agreement is here not so good. For purposes of comparison, we have given in this figure also the curves for the temperature of the air in northwestern England (N. W. England); for the stations around the English Channel (E. Kanal); for Vliessingen and for Borkum. We can detect in the figure a gradual transition in these several curves.

If it is true that an agreement in the above mentioned sense exists between the difference in the surface temperature of the middle and eastern side of the Atlantic Ocean and the surface temperature in the proximity to the Channel at Liepe's station 1, then this correspondence should appear by comparison of Petersen s material with Liepe's material, even though Petersen's material, as we have already said, is not particularly complete on account of too small fields having been used. The uppermost full drawn curve of figure 43, curve I, shows the difference for February between the anomalies of the mean temperature of Petersen's stations 5 and 6 and the anomalies of the mean temperature of his stations 1 and 2. These stations correspond to our two 10° fields 30° to 39° west longitude and 10° to 19° west longitude. The scale of this curve is inverted. At the upper right hand corner, covering the interval from 1898 to 1910, curve II, dotted, shows the difference: Surface temperature 30° to 39° west longitude minus the surface temperature 10° to 19° west longitude from all our fields combined. The full drawn curve III in figure 43 gives the temperature anomalies in February for Liepe's station 1. The full drawn curve IV gives the air temperature in Hamburg in February according to Thraen (1915). Between these curves there is well marked correspondence, particularly in the latter part after 1892, when as we should expect the observations become more complete and trustworthy. The curves for the mean temperatures for the year (September to August) for the surface of the ocean at Liepe's station 1 and for the air in Hamburg are also shown in figure 43 (III and IV, dotted). These curves also show good correspondence although with more exceptions. Particularly the yearly temperatures September to August, 1903, at Hamburg is too low, and shows at this point very little correspondence. The yearly temperature for the calendar year 1903 is on the other hand somewhat high. The average temperature of the calendar years show, moreover, a marked minimum in the year 1902 (see the dotted line IV in figure 43).

VARIATIONS IN THE HEIGHT OF THE WATER OF THE COASTS OF THE NORTH SEA AND THE BALTIC

Another very interesting correspondence may be considered at this point. In figure 42, we give at the bottom some curves which show the variations in the mean height of the water for the year at the different stations on the coasts of the North and the Baltic Seas. For the years 1900 to 1909, the values of the uppermost of these curves (for Esbjerg Korsor and Gjedser) are taken from Brehmer in Ann. d. Hydr., May, 1913. These tables do not, however, extend back further than the year 1900. On the other hand Rosen (1903) has published for the year 1887 to 1910 tables for a number of Swedish Baltic Sea stations. These show a well marked maximum in all the stations for the year 1899. We have computed the mean from all these Swedish results for the years 1898, 1899 and 1900. The difference between 1900 and the two previous years we have employed to piece out in figure 42 the results of Gjedser over these two years. The two lowest curves give the variations in the height of the water at Swinemunde according to Brehmer in Ann. d. Hydr., April 1914, page 207. The full drawn curve gives the mean height of the water as indicated in Brehmer's column 1. The dotted curve gives the mean height of the water after correction for tides (see Brehmer's column 17). The scale indicates centimeters and millimeters for these curves of the variations in the height of the water is inverted. We see a well-marked maximum in the years 1899 and 1903 and a well-marked minimum in 1901 and 1908. These are the same characteristic years of which we have spoken above so often. A comparison between the curves for the height of the water in the North Sea and the Baltic Sea and the curves for the temperature differences in the Atlantic Ocean show therefore a quite remarkable agreement in all years almost without exception. In figure 43 we have extended this comparison to the earlier years 1884 to 1898. Curve V shows the height in the water in Swinemunde according to Brehmer (1914) curve VI, the mean height of the water at the stations on the Swedish coast according to Rosen (1903, p. 4). Curve I shows the temperature difference of Petersen's stations 5 and 6 minus 1 and 2; curve III shows the surface temperature at Liepe's station No. 1, and curve IV gives the air temperature in Hamburg. Correspondence between all these curves is clear. The only considerable difference occurs in the year 1895, when the height of the water should have showed a minimum in order to correspond with the temperatures. There is also some lack of correspondence in 1894.

In the same figure 43 we have shown also the yearly curves for the height of the water in Ijmuiden on the coast of Holland, also in Esbjerg and at Gjedser. These results are given in curve VII. As we see, the curves for the Baltic Sea, Gjedser, and Swinemunde agree excellently with our curve for the temperature difference in the Atlantic Ocean, while on the other hand the curves for the north seacoast do not agree so well, but among them the best agreement is found for Esbjerg. The deviations grow in the westerly direction along the German coast by Norderney, Nordteich, and the Holland coast, but we give here only the curve for Ijmuiden. There is gradually developed toward the west a maximum in the year 1906, whose appearance can already be seen in the curve for Esbjerg, but that in Den Helder is far more considerably developed.

It is obvious that while the curves of the height of the water for the year, particularly in the Baltic Sea, are in complete agreement with our curve for the temperature difference in the Atlantic Ocean in February, only very slight correspondence exists between these curves and the monthly curve for the height of the water in the North Sea and Baltic Sea in February or March (see the dotted curve, fig. 44 V).

As we thought it worth while to compare the variations in the height of the water along the northerly coast with the variations which we have spoken of in the North and Baltic Seas, we undertook with the amiable assistance of the Norwegian Geodetic Survey to make an abstract of the observations of the height of the water at the Norwegian stations. At two stations, Stavanger and Narvik, the observations extended over such a long period of years that we could make such a comparison very favorably. We computed the yearly means from the monthly mean values, and using as normals the mean value of the height of the water for the whole year as computed from all the observations, we determined the anomalies in the height of the water for each year. The anomalies found are expressed in millimeters in the following table and also as curve VIII in figure 43, which is the lowest curve there.

ANOMALIES OF THE HEIGHT OF THE WATER IN MILLIMETERS

	1899	1900	1901	1902	1903	1904	1905
Stavanger	12	—17	7	—61	57	11	—7

	1905	1906	1907	1908	1909	1910
Narvik	—2	28	43	—16	27	—79

The Stavanger observations make a homogeneous series from the year 1899 to 1905, and those for Narvik extend from 1905 to 1910. It must be noted that there are some vacancies in the observations so that the results found cannot pretend to absolute accuracy.

We see that there is considerable similarity between these curves for the Norwegian coast and the curves for Esbjerg in Denmark and Ijmuiden in Holland, but the agreement with the curves of the Baltic Sea is much less perfect, and the same must be said of the agreement with the curve for the temperature difference in the Atlantic Ocean as shown in figure 43, curve II. However, we find in all the curves the same considerable maximum in 1903 and depressions in the years 1902 and 1908. On the other hand, the curve for Narvik shows a maximum in the year 1907, which we have not found in the other curves, whereas the Dutch curves and that for Esbjerg in 1906 show a maximum at a time when the Narvik curve shows a high water-mark. It must be regarded as important that one finds on the whole such similarity in the variations of the height of the water in regions so far removed from one another.

The rule which we have derived from what has been said is this: If the temperature in February in the east fields of the Atlantic Ocean compared with the middle fields (of 30° to 39° west longitude) is uncommonly high, then the level of the water on the whole for the entire year in the North Sea and especially in the Baltic Sea will be uncommonly high. So also will be the temperature of the air in February and in general for the year in Hamburg.

We have spoken here of the difference in the temperatures of the different fields of the Atlantic Ocean. One cannot draw the conclusion from the absolute temperatures in one of the fields because an anomaly may exist over the whole ocean, as in the year 1904. If we examine, however, the curves for Liepe's temperature anomaly station No. 1 (see fig. 43, III), which is a station lying further eastward than our fields and immediately at the mouth of the English Channel near Ouessant, we find there better agreement between the temperature variations and the height of the water in the East sea (see fig. 43, V and VI). The rule that a high surface temperature at Liepe's Station 1, as well as a high air temperature in the northwest coast of middle Europe at Hamburg in February, in general corresponds to a high level of the water in the Baltic Sea during the year shows few exceptions. The explanation is not difficult, and we shall later return to it more at length

in chapter VII. Here we shall only say that a high temperature at the mouth of the Channel points to a current in the water toward the north or northeast, which may be set up by such a state of the air pressure distribution as may cause low surface temperatures in the middle of the Atlantic Ocean. There occurs therefore a difference between these middle and the most easterly regions (see curves fig. 43). This difference is correlated with the masses of water in the North Sea and the Baltic Sea. Accordingly one may predict with the help of temperature observations in the Atlantic Ocean in February whether in that year the water level in the North and Baltic Seas will be on the whole higher or lower than common. This leads to further consequences for the Baltic Sea where evidently the rise or fall of the water within the basin plays a considerable rôle in the entire circulation as well as in all that relates to it.

VARIATIONS IN THE AIR TEMPERATURE OVER THE ATLANTIC OCEAN

On account of the difficulties attending accurate measurements of the temperature of the air, we must expect that the air temperatures amongst our observational material will contain many inaccuracies and accidental errors. On this account, it must be supposed that our temperature values for the air will not correspond very accurately with the real conditions. Nevertheless, it appears that our mean values even for the 2° fields go very well. We have not drawn any curves for the air temperature for the single fields, but only the curves for the difference between the surface temperatures and the air temperatures in each 2° field, as shown in figures 44 to 46. If the air temperatures were altogether untrustworthy these curves would not show good agreement one with another. We find, however, a very good similarity between them, and we see that they, like the curves for the surface temperature, show a gradual transition the further we go from the most easterly fields toward the west. But westward of 44° to 46° west longitude they, like the surface temperatures, begin to show greater irregularities and less correspondence and this was indeed to be expected. Since these curves show such a great agreement each to each, at least in the eastern part of the ocean, it is clear that we may infer that our values for the air temperature in the different fields correspond very well with the truth, and this conclusion will be even more justified for the mean values of our 10° fields (see pls. 42 to 45, curves L).

The average values for the great regions (see curves W and L in fig. 48) show the variations of the air temperatures and the surface temperatures in good agreement, although the variations of the air temperatures are considerably greater that those of the ocean surface. This is particularly the case in February in the middle region of the ocean as shown distinctly in figure 49. In plates 42 to 45, we have given the curves for the temperature of the air (L) and of the water (W) for the separate 10° longitude fields. We find there particularly in February the same tendency to considerably greater variations (with maxima and minima more strongly developed) in the air temperature than in the surface temperature, yet there are many exceptions in the two most easterly as well as in the two most westerly fields.

There are, however, certain marked disagreements between the curves for the air temperature and the curves for the surface temperature of the ocean. This can be observed in the February curve for the air temperature in the middle of our fields along the route Channel-New York (see fig. 48) and also in the mean values for the middle fields of figure 49, which show a secondary minimum in the year 1907 which finds no place in the curves for the surface temperatures. In some of the curves for the fields in the region Portugal to the Azores we also find a tendency to a similar secondary minimum in the curves of air temperatures (see fig. 52). Since it appears in so many curves for different fields, particularly for the 10° fields 30° to 50° west longitude in the route Channel-New York, we cannot think that this depression is merely accidental, but rather that it probably corresponds with a real condition.

The March-April curve for the air temperature for the average of the fields on the route Channel to New York (see fig. 48), or for the four middle 10° longitude fields (fig. 49) show a remarkable rise of temperature for 1904 in relation to 1903 and 1905. There is nothing corresponding to this in the surface temperatures. Since this noteworthy rise of air temperature in the year 1904 is appearing in all the curves for the air temperature in the 10° fields between 20° and 60° west longitude and most strongly so in the midmost of these fields, that is, the field between 40° and 50° west longitude (see pl. 42), we have to do in this case certainly with the [illegible] tion of things and not with mere accidental [illegible] tions. There are still other [illegible] temperature and the [illegible] later.

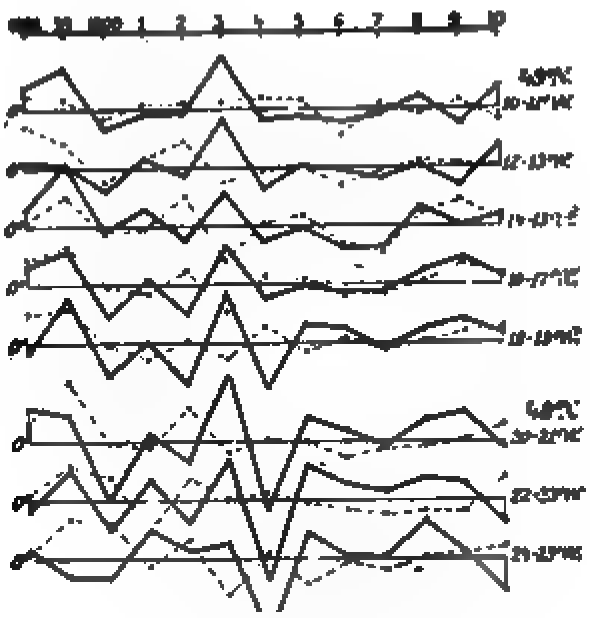

FIGURE 44. FIGURE 45.

FIGURES 44 and 45. Anomalies of surface temperature minus air temperature for 2° fields along the route Channel to New York.

POSSIBLE CAUSES OF THE VARIATION IN TEMPERATURE IN THE SURFACE OF THE SEA AND OF THE AIR

To what causes shall we attribute these remarkable and in part very great variations in the temperatures of the ocean surface and

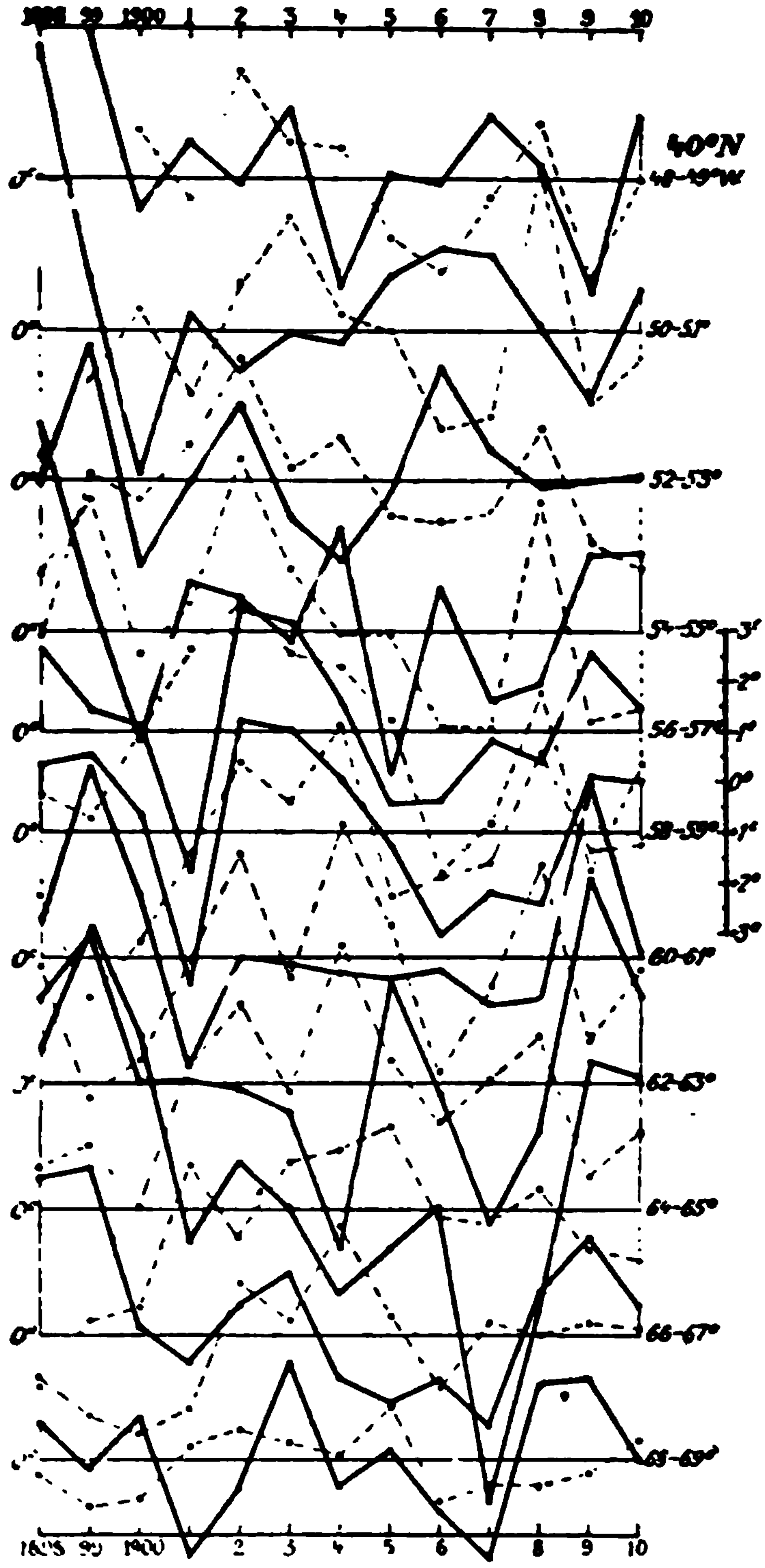

FIGURE 46. Continuation of figure 45.

of the air in different parts of the ocean? We may consider a whole series of possibilities which suggest themselves.

Such temperature variations can be brought about by *variations in the temperature of the water masses themselves* which are transported by the Gulf Stream and other ocean currents. In this case

we should expect a progressive march of the variations from place to place accompanying the transportation of the ocean water- masses.

Variations in the temperature of the ocean surface and the air may also be brought about by *variations in the strength or direction of the winds.* This may work in different ways: In part by the winds transporting warmer or cooler air-masses and tending to warm particular regions of the ocean surface or to cool them. They may act also to produce waves upon the ocean by means of which the upper ocean layers are disturbed and the deeper lying water is brought up to the surface, and thereby the surface is generally made colder. Finally the winds may act by lateral displacement of the surface layers, whereby a field of observation may receive warmer or colder layers of water brought in from elsewhere.

It may also be thought that variations in the temperature of the ocean surface and of the atmosphere may be attributed to the *variations in the intensity of the solar radiation* at the earth's surface. Such variations could for example be brought about by greater or less *cloudiness.* Cloudiness acts in general in summer to diminish the temperature and in winter to increase it on account of its influence on the solar radiation and the outgoing radiation of the earth. But a cause of variation in the solar radiation may occur higher in the atmosphere and depend upon varying quantities of *volcanic dust* thrown high up by great *volcanic eruptions* and remaining suspended in the higher layers of the air for long periods of time.

The temperature variations could be brought about also by variations in the *outgoing radiation of the earth* on account of absorption conditions changed by the influence of carbon dioxide, ozone, or other vapors.

But the temperature variations may also have *cosmic causes* depending for example on *periodic or non-periodic variations in the radiation of the sun,* outside the atmosphere. Such solar changes might produce directly variations in the temperatures measured in the ocean or in the air near the earth's surface or they may act indirectly by calling forth changes in the atmosphere of the earth, such for example as alterations in the thermal relations of the higher air layers or in the atmospheric electric potential or in the terrestrial magnetism or in the earth currents. These changes in the atmosphere could again act in different ways to produce changes in the distribution of air pressure, the formation of clouds and the distribution of temperature on the earth's surface.

VI. VARIATIONS IN INDIVIDUAL FIELDS IN CONSEQUENCE OF THE WATER TRANSFERENCE THROUGH THE REGIONS

Among the possible causes of the variations in the temperatures of the ocean we will first investigate how far it is likely that the observed variations in the surface temperature of the different fields depend upon changes in the quantity of heat available in the water. We may suppose that these changes depend in part upon direct variations in the velocity and volume of the Gulf Stream (off Florida Stream) and the Antilles current which also alter the temperature of it and partly indirectly upon variations of the velocity and volume of the cold Labrador current which may influence its temperature and thereby the temperature of the Gulf Stream, since these cold water-masses must mix therewith.

THE LOW SURFACE TEMPERATURES IN THE YEARS 1903 AND 1904

In order to approach this difficult question it appears simplest to follow the great features of the variations and for this purpose the most striking one to consider first is the great minimum of the year 1904. As already said this minimum shows least in the most easterly fields and increases strongly towards the west. This increase can most probably depend upon the fact that the isotherms in the western region are closer together. One might think that it would thereby occur that in the west they should be nearer the middle action point from which the depression goes out. This supposition is apparently strengthened by the fact that the minimum towards 40° west longitude and from there to 50° west longitude and more is found not only in 1904 but partially in 1903 also. This is observed in our February curves but is more marked in the March-April curves (see figs. 16 to 18).

Since the "cold wedge" projects in the region 48° to 50° west longitude from the Labrador current towards the south into the water-masses of the Gulf Stream (see figs. 5 and 6) the conclusion may apparently be drawn that the region between 40° and 50° west longitude is the action center for our minimum. Here perhaps it was first generated in this way that the Labrador Stream in February, 1903, and yet more in March, 1903, transported uncommonly cold water southward and the water-masses at the Gulf Stream were thereby cooled. From here the cold water was gradually diffused toward the east over the ocean in the course of the year 1903 and, since the addition of cold water from the Labrador Stream increased, it produced a powerful influence over the whole Atlantic

Ocean by February, 1904. The circumstance that the minimum gradually extended also toward the west of 50° west longitude along the water-masses of the Gulf Stream may perhaps be explained by the consideration that the cold water of the Labrador Stream was gradually diffused with the coast current along the south coast of Newfoundland as well as along the southwest coast of Nova Scotia in the year 1903 and yet more in the year 1904. This cold water became gradually mixed with the water-masses of the Gulf Stream further to the west in the open sea.

We may now inquire whether there is evidence that the Labrador current actually transported uncommonly great quantities of cold water in the year 1903. We find, as already mentioned, that exactly in this year an uncommonly great quantity of ice appeared along the Newfoundland banks, which indicates an abnormal development of the Labrador Stream, as Schott has pointed out.

This tends strongly to confirm the correctness of the above given explanation and Schott came also to the conclusion that the water-masses of the Gulf Stream in the year 1903 were uncommonly strongly cooled by the increased activity of the Labrador current, so that this gradually cooled the whole Atlantic Ocean eastward clear to the coast of Europe in the course of the year.

As above pointed out, however, we cannot agree with Schott that the increase of the Labrador current was called forth by a great intensification of the velocity of the Gulf Stream beginning with the year 1903 as he has assumed. Our temperatures of the ocean surface in February do not give the slightest indication of an intensification of the Gulf Stream unless in the most western 10° fields between 60° and 70° west longitude on the coast of America (see fig. 20). In the fields further eastward, in the region of the Labrador current, the surface temperature in February, 1903, was uncommonly low. In this region there was an absolute minimum in the spring of the year just named, in February and yet more in March-April especially in the field between 50° and 60° west longitude (see fig. 20 and pls. 26 and 27).

In relation to the tendency of the Labrador current to cool the water-masses of the Gulf Stream, one must, like Meinardus (1904), take into account that the greatest part of the water-masses of the Labrador current, in consequence of its low temperature and in spite of its small salt contents, is heavier than the water-masses of the Gulf Stream. On this account it tends to sink underneath the Gulf Stream and thereby has a strong tendency to cool the latter

on its underneath layers. But in spite of this it is probable that by the process of mixing the higher layers are in a certain degree cooled also. One must, however, keep in mind that the Labrador current is a surface stream, whose depth is not great, and the volume of the water-mass which it transports is relatively small. Care must therefore be taken not to overload this relatively small current with the work of cooling the whole Atlantic Ocean, as is so often done. It is something quite different, however, to consider that the water of the whole Atlantic Ocean in the north is cooler than it is farther south and that a depression of the temperature within a region must occur when this colder northern water-mass is brought down by one or another cause toward the south.

It is clear that the masses of ice carried along by the Labrador current such as drift ice and icebergs which are driven far toward the south, must particularly by their melting tend to cool the surface layers of the ocean. But meanwhile it must not be forgotten that the quantities of heat required to melt these ice-masses are vanishingly small compared with the quantities of heat which are transported by the water-masses of the Atlantic Ocean currents.

If we examine our material closely in order to see what light it throws upon such a water transportation of heat as we have been speaking of, we may draw the conclusion from the curves of our 10° fields given in figure 20 that the water in February between 50° and 60° west longitude was uncommonly cold and also in the more eastern fields between 50° and 30° west longitude. So far to the east as between 20° and 30° west longitude the surface temperature was in February below the normal (see pl. 26). On the other hand in the most easterly region, between 10° and 20° west longitude, the cooling did not appear to be noticeable. In our last decade group, March-April, in 1903, the surface temperature was further cooled in the fields between 50° and 60° west longitude and this gradual cooling from February to March-April made itself felt in all the fields eastward as shown in figure 20 and plate 27. If we may judge by our curves it continued through the whole year, so that the surface temperatures in February, 1904, were considerably cooler than in March-April, 1903, in all of our 10° longitude fields between 50° and 10° west longitude, but not in the field between 50° and 60° west longitude, as shown in figure 20. In March-April, 1904, the surface temperature began to rise, but particularly in the field between 40° and 50° west longitude, and this rise made itself felt in all the fields eastward thereof. Hence we may assume that at this time the coldest part of the minimum had been passed.

If we consider now the distribution of anomalies in the single decades from decade to decade, as shown in our isopleth diagram of plate 27, we may possibly see indications that in the ocean eastward of 50° west longitude a certain displacement toward the east in the greater and smaller anomalies takes place from decade to decade, but this displacement is not marked and is very irregular, which last is no doubt partially due to the inaccuracy of the material.

RELATION BETWEEN SURFACE TEMPERATURE AND AIR TEMPERATURE

The question whether the variations which we are investigating depend upon changes of the temperature of the masses of water brought on by the ocean currents or whether they depend upon other causes must be settled by the relation between the temperature of the air and the temperature of the ocean surface. Since we have seen the march of the variations in the temperature of the air and of the ocean surface, at least on the whole, go in the same direction, we must expect that if the variations in the temperature of the ocean surface are the primary cause this would precede the variations in the temperature of the air and call them forth.

Since the temperature of the air is on the whole lower than that of the ocean surface, it follows that the addition of colder water-masses by ocean currents tend to bring the temperature of the ocean surface more nearly towards that of the temperature of the air, so that the difference between these would be less than the normal. If the temperature of the ocean surface in consequence of the transportation of warmer masses of water is raised by the ocean current, the temperature of the surface will depart from that of the air and the difference between them will become greater than normal. This is, however, not always the case as one may see by our figures (pls. 42 to 45, curves W and L, and W-L, also figs. 48 to 52). We shall now examine how the special minimum of the years 1903 and 1904 goes with respect to this view.

In the field 50° to 55° west longitude the difference, surface temperature minus air temperature, in February, 1903, was nearly normal, as shown in plate 42. In March-April, 1903, the difference is considerably smaller than normal (see pl. 42). In February, 1904, the difference is a little greater than normal, but in March-April, 1904, it is considerably less than normal. Thus it seems to appear on the whole as if the possibility that the variations in the temperature depend upon variations of the quantity of heat brought by the water-masses is not shut out.

In field 40° to 49° west longitude, plate 42, the temperature of the air in February, 1903, was more than double as much below the normal as the surface of the ocean was under its normal value for this month. In March-April, 1903, the air temperature was somewhat farther below the normal than the surface temperature. In February, 1904, the difference between the surface temperature and the air temperature was not as great as in February, 1903, but greater than it was in March-April, 1903. In all three months, it was greater than normal. In March-April, 1904, on the other hand, the difference between surface temperature and air temperature was less than normal. In this field therefore we cannot say that the relations point to the view that the temperature variations were primarily caused by changes in the temperature of the water-masses brought in by ocean currents.

In field 30° to 39° west longitude (pl. 42) the difference between the surface temperature and the air temperature in February, 1903, was normal, in March-April, 1903, it was greater than normal, and in February, 1904, it was considerably greater than normal. On the other hand in March-April, 1904, it was less than normal.

In field 20° to 29° west longitude (pl. 43) in February, 1903, the difference between the surface temperature and the air temperature was less than normal, in March-April, 1903, somewhat greater than normal, and February, 1904, considerably greater than normal, and in March-April somewhat less than normal. We have here therefore the same run as in the 10° longitude field 30° to 39° west longitude and that appears scarcely to favor the view that changes in the temperature depend primarily on the variations of temperature of the water-masses in the ocean current.

In field 10° to 19° west longitude (pl. 43) in February, 1903, the difference between surface temperature and air temperature was considerably less than normal, but here there was a secondary maximum in the surface temperature. In March-April, 1903, the difference between the surface temperature and the air temperature was greater than normal, February, 1904, it was greater, and in March-April somewhat less than normal. Of this field we can therefore say that the February curves indicate that the variations in the surface temperature and the air temperature were not [illegible]marily due to temperature changes of the masses of water [illegible] on by the ocean currents.

If we consider now the relati[illegible]
air temperature in [illegible]

together as a whole, as shown in figures 48 and 49, we conclude that there is scarcely any indication that shows definitely that the variations in the surface temperature are first in point of time, and depend on changes of temperature in water-masses brought on by the ocean current. One, however, obtains the impression that the variations in the air temperature go before the variations in the surface temperature of the water; because, as we have said, in most cases these are greater in the magnitude both of the positive anomalies and the negative anomalies than the variations of the surface temperatures. A clearer impression of this relation is obtained perhaps by the study of the curves in the southern fields, particularly 41° to 45° north latitude in plates 44 and 45 and in figures 50 to 52.

On the whole we have not obtained in this way a final answer to the question whether the marked minimum in the years 1903 and 1904 depends upon the transportation of cold water or not.

TEMPERATURE VARIATIONS IN THE DECADES AS SHOWN IN OUR ISOPLETH DIAGRAMS

Considering the variations in the other years, we must first investigate whether our isopleth diagrams for the decades (see pls. 17, 19 to 41) give indications that these variations are brought about by the transportation of cold or warm water-masses. We must, however, recognize that only variations with short periods could produce true displacements in so few decades (only seven) as are included in our diagram. Variations with longer periods would evidently produce effects diffused over all seven of the decades and only at the beginning or the ends of such variations would it be expected that displacements would appear in our isopleth diagrams. There is still another consideration of perhaps even greater weight which must be kept in mind. If the variations are brought about by the transportation of cold or warm water-masses they should be indicated on our isopleth diagrams by a gradual displacement from the left toward the right, that is, from the west toward the east, from decade to decade, and this would imply that the current moved in an easterly direction along the course of our region of investigation. If it crossed this course at right angles or diagonally thereto there would be no clear displacement in the diagrams. But in fact, as already mentioned, we must assume that the current cuts at least in several places our route from the Channel to New York and does not go along with it. The isopleth diagrams therefore cannot show

on the whole a well marked tendency to the displacement of the anomalies from decade to decade. In single years, as for example in the year 1910, there came in the second and third decade a negative anomaly which spread out over a greater part of the investigated region and then suddenly ceased. In the fifth decade, moreover, there appeared a well-marked positive anomaly in the same region. Such a variation can scarcely be brought about by the transportation of cold water unless it should be a wandering minimum of very short period, and it must therefore probably depend upon other influences which rule only in the second and third decade. In the year 1905, for example, there was from the first to the third decade a well-marked positive anomaly over a greater part of the region which, however, ceased in the fourth and fifth decades, when negative anomalies occurred over nearly the whole region. Here also it cannot have been a transportation of warm water in the first decades which ceased immediately after, for in this case this warm water must in all events have appeared in the later decades also. Of course it might have been that the current was more or less at right angles to the investigated region and the period of time that the water was passing was so short that all the warm water passed by between the third and fifth decade. But such an assumption is not very probable.

POSSIBLE SIGNIFICANCE OF THE TRANSFERENCE OF WATER-MASSES BY OCEAN CURRENTS WITH RESPECT TO TEMPERATURE VARIATIONS

A possible indication of the fact that some of the variations may really depend upon the transference of water-masses of different temperature is found by comparison of the different temperature curves for the different 10° longitude fields in the southwest corner of the Portugal-Azores region and northeasterly toward the most easterly field of the route Channel to New York. In figure 47 are superposed, first, the mean of the temperature curves for the two most southwesterly 10° longitude fields in the Portugal-Azores region, that is to say, the fields between 37° and 39° north latitude and between 20° and 40° west longitude; second, in the same way the mean of the temperature curves for the two more northerly lying 10° longitude fields between 39° and 41° north latitude and between 20° and 40° west longitude. Besides these are also collected the temperature curves for each of the two most northerly fields of the Portugal-Azores region between 20° and 30°

west longitude and finally also for the most easterly fields between 10° and 20° west longitude of the route Channel to New York. As is easily seen there is a gradual development in these curves from SSW. towards NNE., while the curves on both sides of this course as well toward the northwest as toward the southeast have a quite different nature. The conclusion seems therefore natural that from the southwest corner of the Portugal-Azores region water-masses of different temperature were transported in the direction of NNE. and it is in consequence of this transportation that an uninterrupted relationship exists between these fields.

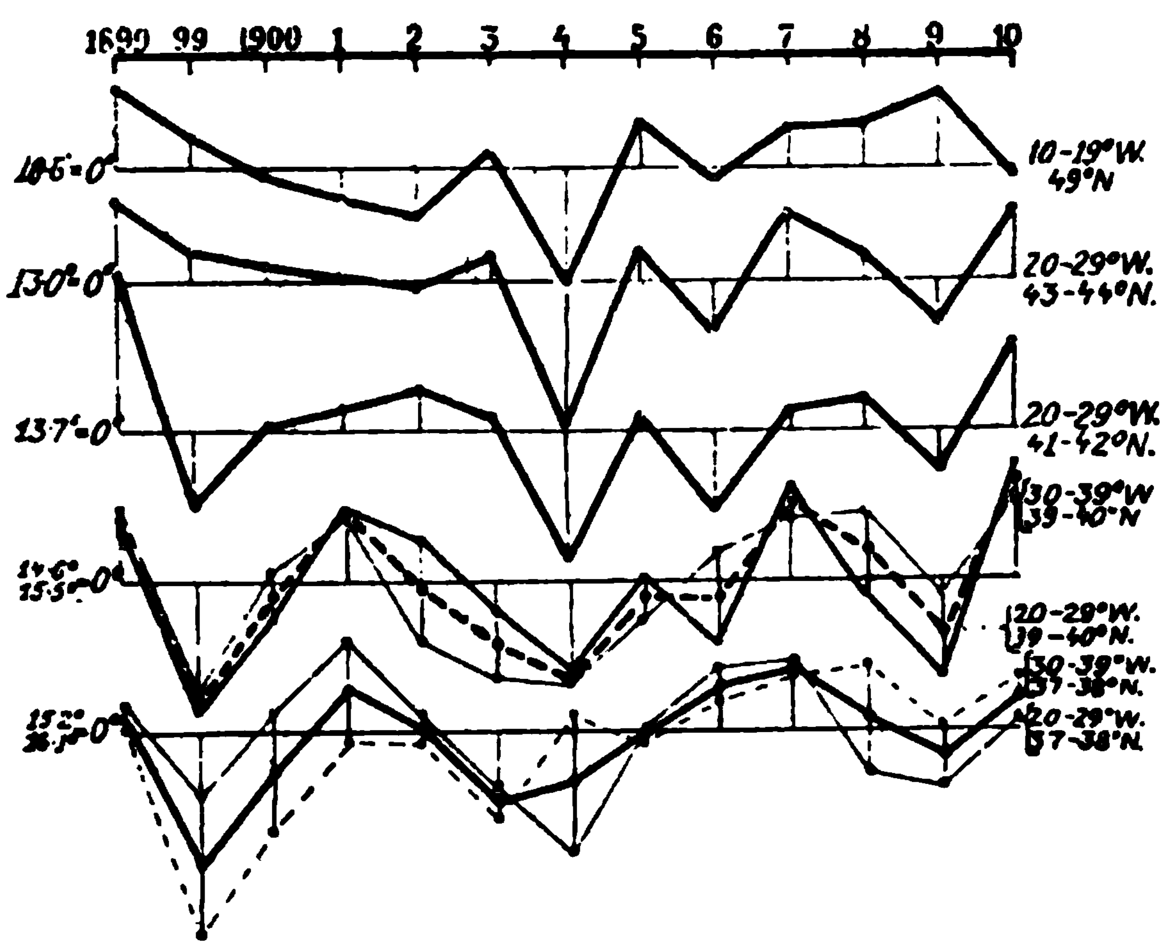

FIGURE 47. Curves for the anomalies of the surface temperature in February in the fields indicated on the right.

It also points in the same direction that, as earlier remarked, the current is often more at right angles to our observational region than along it and the transportation in a west to east direction within our fields is therefore relatively small and less noticeable in our observational series and isopleth diagrams.

According to these results it appears that the islands or bands which are found in the decade isopleths (see, for example, 1910, pl. 41) perhaps are produced by wandering minima or maxima, but more probably depend upon particular wind relations or other local circumstances which one must study on the decade charts of air pressure and wind distribution.

DISPROOF OF THE ASSUMPTION THAT THE OBSERVED TEMPERATURE VARIATIONS ARE DUE PRINCIPALLY TO VARIATIONS IN THE OCEAN CURRENTS

Counter to the assumption that the variations in the surface temperature of the North Atlantic Ocean depend mainly on the transportation of colder or warmer water-masses along with the Gulf Stream drift, tends the fact already mentioned, namely, if the surface temperature in February in the middle of the North Atlantic Ocean (30° to 39° west longitude) in comparison to that of the most easterly part (10° to 19° west longitude) is low, then the surface temperature on the coast of Europe near the Channel is high as well as the air temperature over the northwest coast of Europe at Hamburg and the yearly mean height of the water in the North Sea and in the Baltic Sea. If, however, the surface temperature in the middle part of the North Atlantic Ocean is high in relation to that of the eastern part, all this is reversed. Obviously another cause must produce this result and we shall return to this later.

Opposed to the assumption that the minimum in the years 1903 and 1904 depended only on the transportation of cold water with the Gulf Stream is the circumstance that this minimum, particularly in the year 1904, extended over so great a part of the earth. In the first place we find it not only over the whole of the region of the Atlantic Ocean investigated by us, but also yet further south near the equator, as shown in the Dutch fields (pl. 15, fields 19 to 20) where there was a minimum which agreed completely with ours and which also occurred in the yearly temperature (see fig. 39 and pl. 28). In the western Danish fields north of 50° north latitude, shown in figure 33, and also on the equator between 0° and 1° north latitude and 29° to 32° west longitude, as we shall see later, we find the same minimum in the yearly temperature (see fig. 60, curve IXb). In the Indian Ocean also there appeared a minimum in the year 1904, as is shown by the Dutch records for the 10° squares (see fig. 62, curve VIII).

Not only in the ocean was there a minimum in February, March-April, and the whole year 1904, but also in the atmosphere there was a minimum over a great region of the earth, particularly marked in the tropics, and further appearing in the average temperature for the year on the whole earth (see fig. 60) of which we shall speak later. We must therefore believe that there was a more general cause at work, for it is not possible that a mere local transportation of relatively cooled water into the Atlantic Ocean could have produced such general effects.

VII. RELATION BETWEEN THE TEMPERATURE AND THE AIR PRESSURE DISTRIBUTION OVER THE NORTH ATLANTIC OCEAN

If one seeks to determine the influence of the winds on the surface temperature of the ocean he must examine the condition of the surface layers in the different seasons of the year. In northerly latitudes where the evaporation is less than the precipitation the salt content is increased in winter in consequence of the mixture of the underlying layers by a vertical circulation, while in the summer the salt content diminishes in consequence of the precipitation which being warm would remain on the surface and thereby a lighter layer is formed. Besides this the upper surface water in a large part of the ocean is diluted by the coast water and also by the polar water. These surface layers spread about over much greater areas in summer than in winter, because their specific gravity is considerably smaller partly by the increased dilution and partly by warming. If, however, the evaporation is greater than the precipitation, the yearly march is reversed and the highest salt contents at the ocean surface is found in summer and the lowest in winter.

ACTION OF WINDS ON SURFACE TEMPERATURES

How does the action of the winds on the surface temperature adapt itself in different cases?

As a general rule we must expect that if the wind in the field blows from regions of the sea where the surface is warmer, then the surface temperature in the field in question will tend to rise because warmer waters will be brought by the winds. But if the winds come from a region of colder ocean surface, the reverse will happen. In particular cases, however, there are many deviations from this rule.

If the sea is covered with a thin top surface which is warmer than the water lying below, then a strong wind, by stirring the water in the upper layers may produce a lowering of surface temperature even though this wind comes from the warmer regions of the sea. If the ocean has a fresh-water surface, which by reason of its small salt content is lighter than the water lying below, and this layer by the outward radiation in winter becomes colder than the underlying layers, then a strong wind by stirring up the water may cause a rise of the surface temperatures, even if it comes from colder regions of the ocean.

If at one place a strong wind occurs and thereby stronger surface currents are produced without a corresponding increase in the currents in the region behind, then an increased transportation of the surface water must be in part made up by water taken from the underlying layers. If this is colder, then the surface temperature must sink thereby, even if the wind itself comes from warmer layers of the ocean. This in many cases occurs suddenly by reason of local winds, without continuing long enough to appear in the monthly means.

The above mentioned exceptions to the general rule concerning the action of the wind on the surface temperature of the ocean are those which must be expected to make themselves least felt in the North Atlantic Ocean in the months of the year which are included in our investigations. The surface of the ocean is then most cooled and the convection streams are in the greatest degree of homogeneity in a vertical direction.

When the sun begins to warm the ocean surface in the spring, it would be otherwise and it may then be understood, how, as we shall later describe, the best agreement between the wind relations and the variations of the surface temperature is found in February.

COMPUTATION OF AIR PRESSURE GRADIENTS AND WIND DIRECTION

The process employed by Meinardus of determining the air pressure difference between some few chosen places does not serve to exhibit clearly the influence of the air pressure distribution and the winds which arise from it on the observed variations in the surface temperature of the ocean. To be sure, one obtains in this way a kind of sample of the variations in the strength of the atmospheric circulation, but the process does not give us the variations in the direction of the circulation in the different regions, and this is exactly what it is necessary to know.

We have found that an investigation of the air pressure distribution (and the wind relations depending thereon) may be obtained most conveniently for our purpose with the help of the monthly charts of the air pressure distribution of the Atlantic Ocean, which are based on the daily synoptic weather charts published by the Danish Meteorological Institute and the Deutschen Seewarte. Publications of this kind are available for the years 1898 to 1908. Before the printing of this memoir we obtained, through the kind assistance of Mr. Ryders, Director of the Danish Meteorological Institute, proof-sheets of the isobar charts for January, February, and March, 1909 and 1910.

For each of our 10° longitude fields in the course Channel to New York and for each field of 10° longitude and 2° latitude in the region Portugal to the Azores, for the months January and February of each year, and in the region Channel to New York, also for the month of March, we obtained the mean direction of the isobars (in the direction of the wind, according to the barometric law of the wind). We have also found values for the average intensity of the air pressure gradients, which we obtained by measuring the distance between the isobars and taking the reciprocals of these values. As a unit, we have taken the thousandth of the reciprocal value of the distance between the two-millimeter interval isobars, measuring this distance on the charts to millimeters. If, for example, the distance between two such isobars was 6 millimeters, then the gradient numbers according to our figures would be $1000 \div 6 = 167$. As a rule we have taken mean of the distances between several isobars. By making progressive vector diagrams for each month in which the direction of the vectors of that month for each year are drawn according to the isobar angle, and the lengths are given by the relative gradient numbers just described, we have obtained average isobar directions for each of the months January, February and March in each of the 10° longitude fields for the eleven periods 1898 to 1908.[1] This period is unfortunately not identical with the eleven-year period 1900 to 1910, which we have employed in the determination of the temperature normals.

Next we have determined the anomalies of the isobar direction for the different months and years as deviations from the average direction for these months. Deviations toward the south, that is to say, when the isobars are directed southerly of their normal positions, we have designated as negative, and deviations toward the north as positive. The product of the gradient number and the sine of this anomaly angle is then used as a measure of the possible influence of the wind on the surface temperature. In doing so, we consider that the normal position of the surface isotherm is dependent on the average direction of the isobar and that a deviation from this must produce lateral displacements of the isotherms. The sine of the deviation angle would be equal to the component of the air motion at right angles to the average direction.

This process obviously cannot pretend to any great degree of accuracy. For example, it is not easy to know in advance which is

[1] Unfortunately we received the isobar charts for 1909 and 1910 too late to carry through this computation.

more important for the surface temperatures, the direction of the wind or its strength. Furthermore the influence on the surface temperature is certainly not simply proportional to the strength of the wind and still less is it proportional to the sine of the angle, positive or negative, which the wind makes with the direction of the normal wind.[1] But in spite of this inaccuracy the process gives the means of determining the influence of the wind on the variations of the surface temperature qualitatively and to a certain degree quantitatively at least in the colder part of the year, with which we have here to do.

ANGLE BETWEEN THE DIRECTIONS OF THE ISOBARS AND THE ISOTHERMS

The average isobar directions for January, February, and March for the eleven-year period 1898 to 1908 are given in tables 12D and 13D, and for January and February they are also given on the chart, figure 7 (see also pl. 1, and for March, pl. 7). The relation between these isobar directions and the directions of the isotherms is of interest. In most of our 10° longitude fields the isotherms cut the average direction of the isobars in a pretty constant angle (see chart fig. 7). An exception appears in the four eastern fields near the Spanish Peninsula, as well as in the most westerly field near the American coast. The same holds for the two fields south of Newfoundland Bank where the current direction is strongly influenced by the ocean bottom. Also in the four fields for the Danish observations north of 50° north latitude, the isotherms do

[1] Several considerations may be mentioned which have an influence but which the method takes no notice of. For example, if the isobars in a field during a month have a normal direction, then the deviation angle is equal to 0° and the product of the sine with reciprocal value of the air pressure gradient will also be equal to 0, however great the latter value may be. Now it is possible that the increased strength of a wind of a favorable direction tends to raise the surface temperature in a field with warm ocean currents on the surface. Thus the increase of the strength of the wind even if it blows in the normal direction may produce an increase of the surface temperature because it increases the velocity of a warm current. Indeed it is possible that a wind which is uncommonly strong may raise the temperature even if it comes from a direction which would have a negative sine value to the normal direction. We can make no consideration of these conditions in our process. On the other hand, it is not certain that an increase in the strength of the warm wind, that is to say, one whose direction is on the positive side of the normal direction, would always have the tendency to raise the surface temperature of the ocean.

not cut the isobars at a constant angle (see fig. 7). But in all our fields in the open ocean south of 50° north latitude between 20° and 40° west longitude and furthermore in the fields between 10° and 20° west longitude in the route Channel to New York, the angle made by the average isobar directions for February with the isotherms for February varies only between 29° and 47° and is in the mean 39°.

According to theoretical computations, in consequence of the rotation of the earth the direction of the currents which the wind causes should be inclined at the angle of 45° to the wind direction. The agreement between our angle and this angle seems extraordinarily good, since they differ by only 6°. The isotherms to be sure do not follow exactly the same direction as the surface current, for the latter has a more northerly direction. On the other hand, the wind does not move exactly in the isobar directions, but somewhat to the left of this as is shown in chart, figure 8.

We must keep in mind that it is not alone the wind relations of February which have influence upon the temperature distribution at the surface of the ocean in February, but probably also the wind relations in the previous time. It seems therefore more justifiable, theoretically at least, to take the mean value, for example, of the isobar directions in January and February to compare with the February isotherms, and we have done this in the chart, figure 7, and in plate 1. With this modification we find that the angle between the isobar directions and the isotherms is on the whole very nearly the same as found above. In most of the stretch of free ocean surface it comes to about 40°. It varies between 21° and 53°. The mean is 37° instead of 39° as given above.

In the most easterly part of the Atlantic Ocean near the Spanish Peninsula, obviously the ocean currents set up by the wind are influenced by the coast and the coastal topography. The average isobar directions make another angle with the isotherms. Also in the neighborhood of the American coast the isotherms are strongly influenced by the Gulf Stream and the ocean bottom conditions, so that one should not expect here so good an agreement between the directions of the isobars and those of the surface isotherms, for here the wind has less influence on the current. We find here, accordingly, quite another angle between the isobar and the isotherm directions. This is also partially the case in the fields south of the Newfoundland Bank. However, it should not be overlooked that, as figure 8 shows, the wind in this region blows much to the left

of the isobar directions. In the open ocean south of 50° north latitude, however, where one ought not to expect that outside influences should be so important, we find a definite relation between the directions of the average isobars and the average isotherms. This proves nothing with certainty concerning the general tendency of the winds to create ocean currents particularly as we see that in the open ocean north of 50° north latitude the relation does not hold, and in the ocean southwest of Ireland we must assume that the surface current goes toward the left of the isobar directions and not towards the right (see the arrows in fig. 7). However, the peculiar relation pointed out between the isobar direction and the isotherm direction in the middle part of the North Atlantic Ocean points to the fact that the wind here bears a strong influence on the motion of the surface waters. We must in this case therefore expect that it has also a strong influence on the variations of the surface temperature in consequence of its tendency to displace the water-masses on the surface.

COMPARISON OF THE VALUES OF THE AIR PRESSURE GRADIENT WITH THE TEMPERATURE ANOMALIES

In tables 12 D and 13 D we give for the months of January and February in each year the values found for the deviations of the isobars from the normal direction in each of the 10° longitude fields. Also the reciprocals of the values of the intensity of the air pressure gradients as well as numbers obtained by multiplying these intensities by the sines of the angles of deviation of the isobars. These values are also given for the months of January and February for the resultant between the directions of the isobars for these months. For the northerly route, Channel to New York, the same values are given for the month of March. Since the values for the mean gradient effect for January and February are obtained by vector analysis from the resultant for the isobar directions of these months, the results obtained are not always equal to the mean of the values of the two months.

On the chart for February and for March-April of the different years (see pls. 16 to 41) we give for each of our 10° longitude fields arrows whose direction and magnitude indicate the resultants for the isobar directions and the air pressure gradients.[1]

[1] It must be recalled that the charts for February show the following:

Air pressure. The arrows for the ocean fields (see pl. 15, 1 to 24, and pls. 1 to 7) give the results for January and February. The arrows for the other

We give also the anomalies of the surface temperature in tenths of a degree (printed in whole numbers without rings). The bold-faced numbers show positive anomalies and the lighter face italic numbers negative. The numbers in rings give air temperature anomalies in tenths of degrees for these fields. The heavy rings indicate positive and the lighter ones negative anomalies. We have added the direction of the isobars and the strength of the air pressure gradients as well as the anomalies of the ocean surface temperatures for the 10° longitude fields for the Danish observations north of 50° north latitude, and also the results for Liepe's 1° fields (his stations I to VII, pl. 15, for the years 1898 to 1903).[1]

If the directions of the isobars in the single years run on the side of the normal direction which tends to raise the temperature, the arrows are shown as heavy full-drawn lines. For isobar directions on the opposite side which tend to cool, the arrows (with the exception of those in Liepe's fields III to VII and the Dutch fields 19 to 20, pl. 15) are shown as heavy dotted lines. There are also indicated on the charts by weak arrows the average direction and magnitude of the resultants for the action of the air pressure gradients for the interval 1898 to 1908.

We give also upon the charts gradient arrows and surface temperature anomalies for the two already mentioned Dutch 10° fields (pls. 15, 19 to 20) for the years 1900 to 1910, also for stations on the Norwegian coast, on the Faroe Islands, and in Iceland. Finally we have introduced the monthly anomalies of the air temperature for different stations in North America, West Indies, South America, Greenland, Europe, and Africa. These numbers are inclosed

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fields (on the coasts, that is to say at Hamburg, Torungen, Stad, Ireland, Hebrides, Shetlands, Faroe Islands) on the other hand give results only for February.

The temperature (both water and air) is always for February alone.

The charts which are headed March give:

Air pressure. The arrows give in all cases the air pressure gradients for the month of March.

The temperature is given for our fields 1 to 6 (pl. 15) for the time interval March 15 to April 13, for the Danish fields 21 to 29 (pl. 15) from March 16 to April 15. For Liepe's fields I to VIII and the Dutch fields 19 to 20 (pl. 15) the temperature is given for the mean of March and April. All air temperatures outside of our fields 1 to 6 are for March, as are also the water temperatures at the coast stations 30 to 45 (pl. 15).

[1] It should be noticed that the 20 years normal values of the temperatures at Liepe's stations which are computed for the period of time, 1884 to 1903, are employed as the eleven-year normal values for our fields 1900 to 1910.

in rings, heavy rings for positive and light for negative anomalies.[1] The pressure gradients are also given by arrows for stations of the British Isles and also for Hamburg. See further details in the explanation of the tables.

In plates 16 to 41, we have drawn on the left hand pages at the

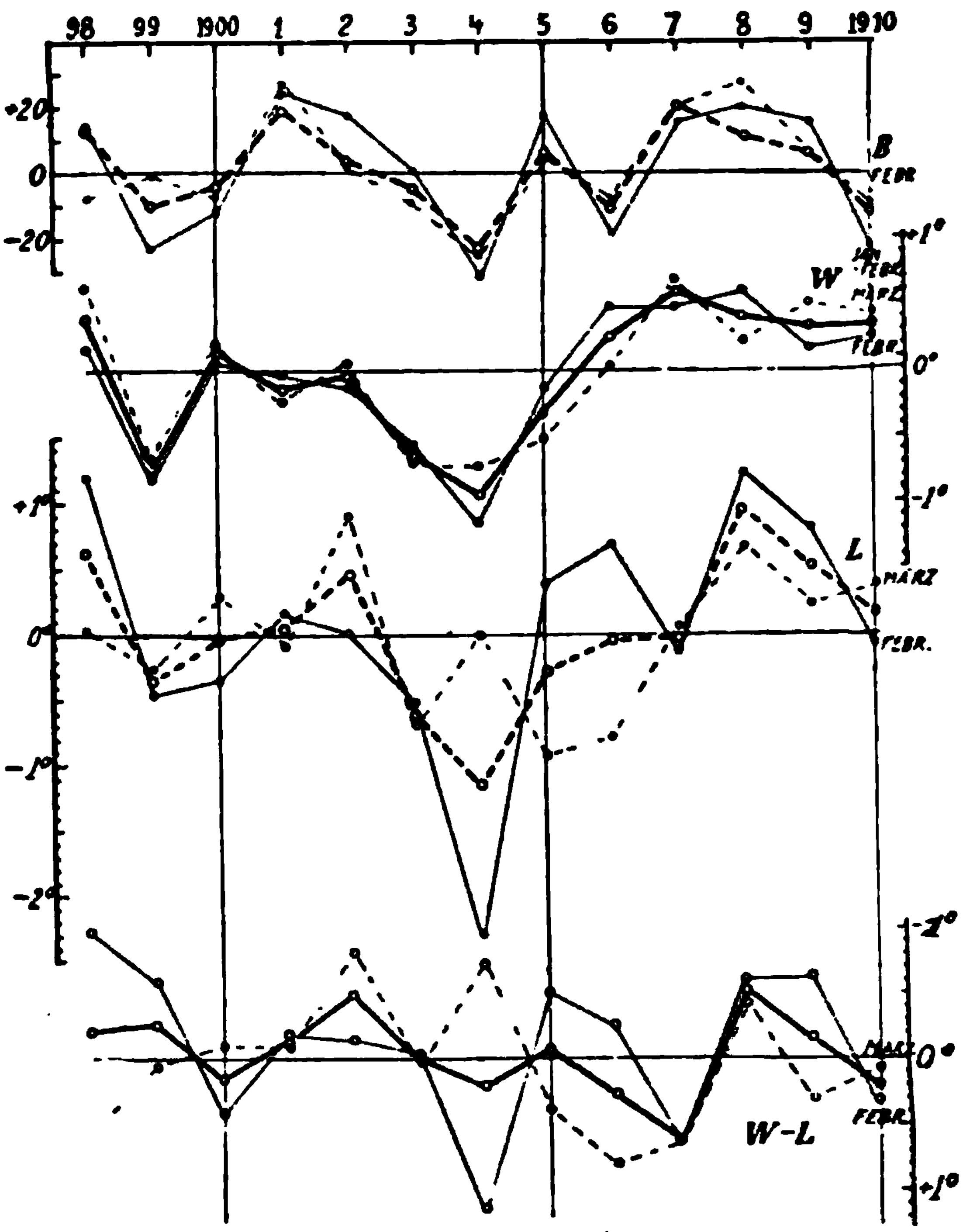

FIGURE 48. The curves give the mean values for all six 10° longitude fields along the route Channel to New York. B: the air pressure gradients for January-February, February-March, and for the mean value for the months January, February, and March indicated by a strong dotted line. W: the anomalies of the surface temperatures. L: the anomalies of the air temperatures. W-L: the anomalies of the difference: surface temperature minus air temperature. W, L, and W-L apply for February as indicated by weak full-drawn lines, for March-April as indicated by weak dotted lines, and for the mean values of both decade groups, February and March-April, as indicated by strong lines.

bottom curves for the year, which give the local variations of the air pressure gradients across the Atlantic Ocean (curve B). The January curves are given by weak dotted lines, the February curves

[1] The normal temperatures for all these stations, with the exception of Liepe's stations, are computed for the same interval of time, 1900 to 1910, as for our fields.

by weak full drawn lines and the average result for both months by strong dotted lines. There are also given curves for the anomalies of surface temperature (curves W), for the anomalies for the air temperature (curves L) and finally the anomalies of the surface temperature minus the air temperature (curves W-L). The figures at the middle and right hand side relate to the route New York to the Channel. The figures on the left relate to that from New York to Portugal, although the three most westerly 10° fields of the route New York to the Channel are included in these figures while the values for the three easterly fields are the mean values of all 10° longitude fields between Portugal and 40° west longitude. These are made up of all fields between 37° and 35° north latitude and between 10° and 20°, 20° and 30°, 30° and 40° west longitude.

If we examine these charts for the different years closely and compare them with the curves of the figures, we see that on the whole there is a good correspondence between the anomalies of the surface temperature and the air pressure gradients. This comes distinctly to view both in the charts and in the figures. Particularly good is the agreement in the years when the air pressure gradients were large, that is to say, when the air circulation was strong, as for example, in the years 1899 and 1903. The years 1898, 1906, 1907 and 1908 may also be included in this remark. The agreement is less good in the years when the air pressure gradients are less and in consequence the wind was weaker. In this connection we may particularly mention the years 1900 and 1902 when the agreement was less satisfactory.

THE WINDS ARE THE PRINCIPAL CAUSE OF TEMPERATURE VARIATIONS ON THE SURFACE AND IN THE AIR UPON THE NORTH ATLANTIC

Already the charts and curves of these plates have sufficed to show that the wind in most years has a very strong influence on the temperature variations in the field we have investigated. We obtain perhaps the strongest impression that this must be the case if we examine the curves of plates 42 to 46 which give for each of our 10° longitude fields and for the Danish fields the variations from year to year in the anomalies of the pressure gradients for the different months (January to March), of the surface temperatures, of the air temperatures, and of the surface temperatures minus the air temperatures. These curves show us that the agreement is not particularly good in the most western and most eastern fields. On

the other hand, in the middle fields, in the open ocean, the agreement on the whole is extraordinarily good and without doubt shows that the wind has a decisive influence on the temperature variations of the water and the air.

It is still more clearly seen that the relation between the variations in the direction and strength of the air pressure gradients and the

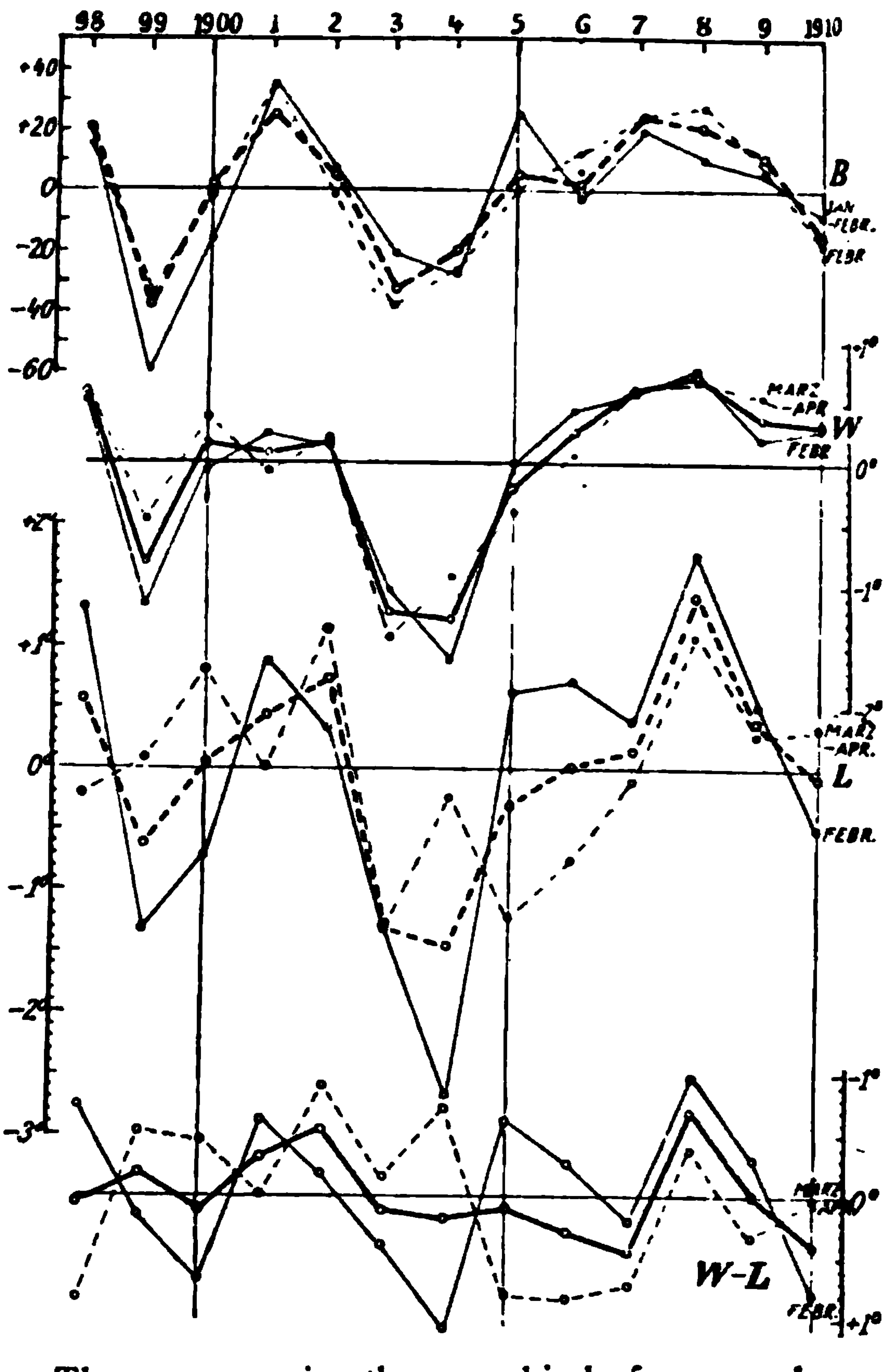

FIGURE 49. These curves give the same kind of mean values as in figure 48 but only for the four middle 10° longitude fields between 20° and 60° west longitude along the shipping route Channel to New York.

variations in the surface and air temperatures are in agreement if we examine the mean values for great regions. Figure 48 gives the mean of all six 10° longitude fields along the route Channel to New York. The similarity between the curves of the air pressure gradients (B) and the curves for the temperature anomalies in the water (W) and in the air (L) is undeniable. But particularly

great is the similarity if we omit from the calculation of the mean value the most easterly and most westerly 10° fields, and confine ourselves to the middle part as we have done in figure 49 (see also fig. 51 and 52). We see that in these curves the agreement with few exceptions might be called complete.

The values found for the single fields in the Portugal-Azores region in many cases show poorer agreement (compare pls. 44 and 45). But it must be remembered on the one hand, that our observational material here is less complete, that is, on the whole there are fewer observations for these fields. On the other hand, our process of determining the strength and direction of the wind is not accurate enough for this region, where we are in the influence of the anti-cyclonic high-pressure region near the Azores and also approach the region of the trades. However, the average of the fields, as shown in figures 50 to 52, has remarkably good agreement, in fact even a more complete agreement than in most of the other regions.

In the 10° longitude fields of the Danish observations north of 50° north latitude, as we have already said, we have based the values found for the surface temperatures on too few observations, so that we could not expect here as completely satisfactory agreement as elsewhere. In this region of the ocean, furthermore, the air pressure observations for the months within which our investigation is confined are so few in number and are so scattered that the monthly isobars on the charts are somewhat hypothetical. However, in spite of this we have drawn curves of the air pressure gradients and the surface temperatures both for January-February and for March-April for these 10° longitude fields (see pl. 46). We find the agreement between them better than the unsatisfactory quality of the material would lead us to expect, particularly for the field between 30° and 39° west longitude. In the most easterly field here, as also farther south, the agreement between the curves for the air pressure gradients and for the surface temperatures is not very good. But these curves have a similarity with the corresponding more southerly ones.

If the wind is a principal cause of most of the observed variations in the surface temperature from year to year, then we must expect that variations in the direction of the isobars and the intensity of the air pressure gradients would primarily influence the air temperature and bring still greater variations in this than in the surface temperature of the ocean. Our curves in figures 48

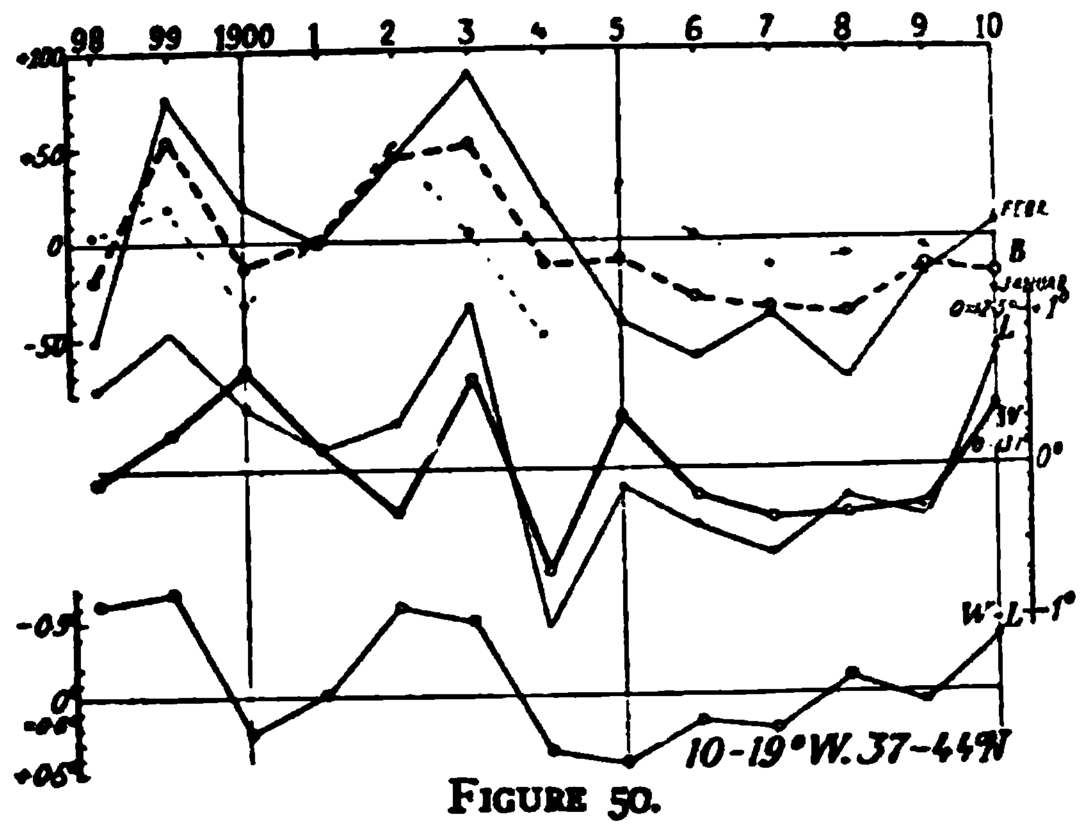

FIGURE 50.

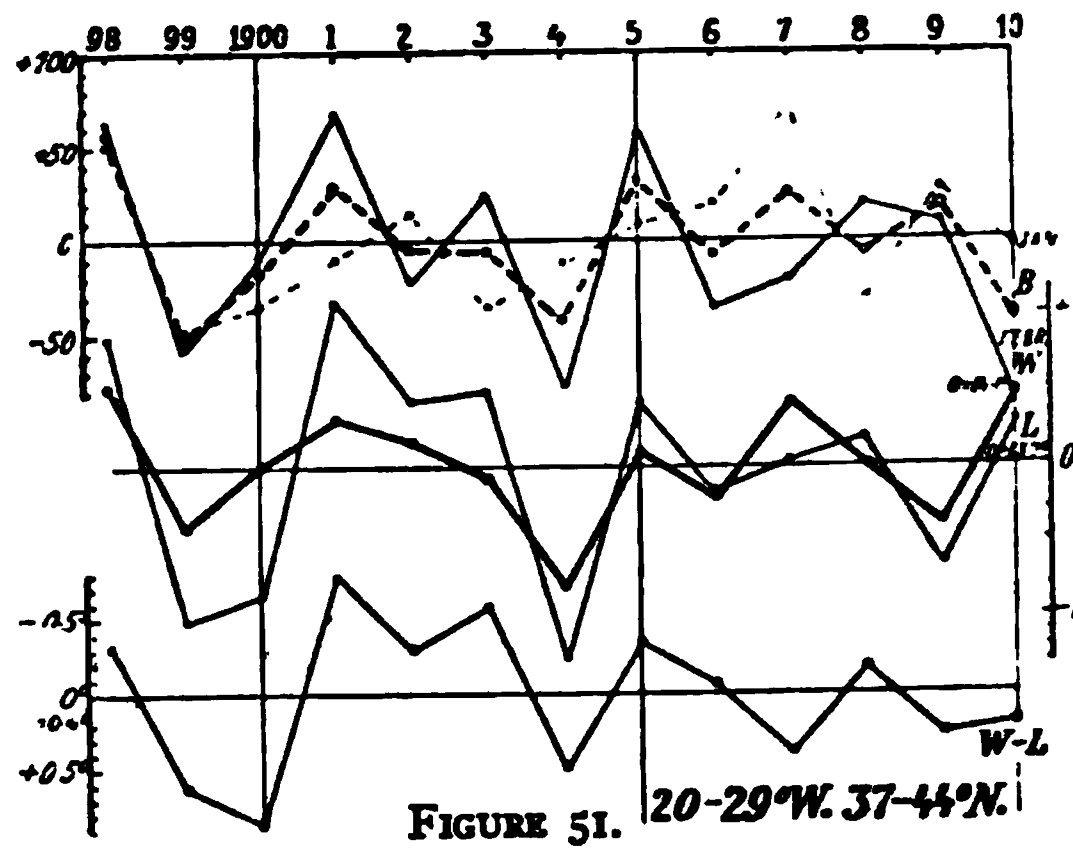

FIGURE 51.

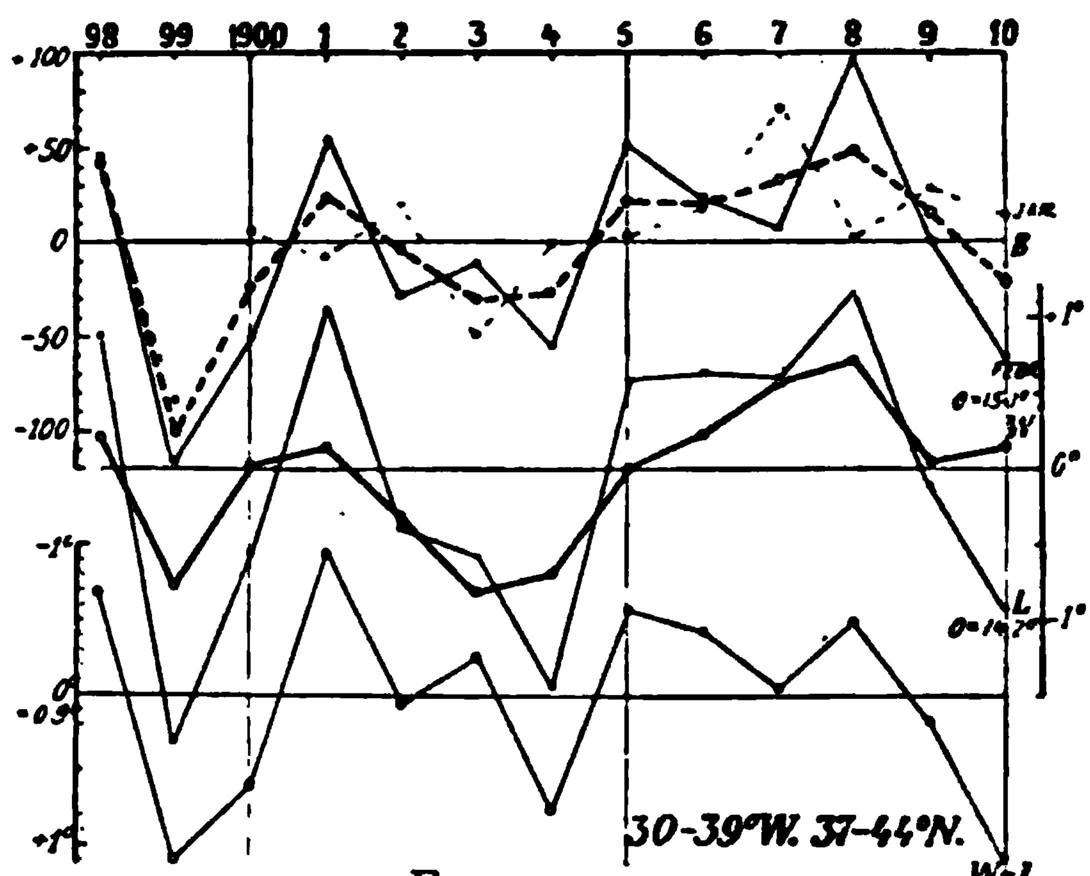

FIGURE 52.

FIGURES 50 to 52. Average curves for all fields between 37° and 45° north latitude and between 10° and 20° west longitude (fig. 50); between 20° and 30° west longitude (fig. 51) and between 30° and 40° west longitude (fig. 52). B: curves for the air pressure gradients for January, for February and for the resultant for both months (indicated by strong dotted lines). W: curve for the anomalies of the surface temperature from February 3 to March 4. L: curve for the anomalies of the air temperature from February 3 to March 4. W-L: curve for the anomalies of the surface temperature minus the air temperature from February 3 to March 4.

to 52 show that this on the whole is the case to a high degree, and furthermore they show, what was also to be expected, that for the variations in the air temperature in February the variations of the air pressure gradients in February are of greater importance than those in January. For it is obvious that variations in the wind act more directly upon the temperature of the air than upon that of the water, whose mass is more slowly affected.

Although our observational material for the air temperature is so imperfect, yet the curves for the air temperatures in February and for the pressure gradients particularly in February show an unexpected agreement for the most of the ocean regions. It is clear that the variations of the air temperature are much greater than those of the surface temperature. It is also to be expected, as already said, that the action of the wind would not only make itself first felt on the air temperature, but also would produce in it greater variations than in the surface temperature of the water. The investigation of the anomalies of the surface temperature minus the air temperature, as in tables 9 to 11, W-L, must therefore be of interest. These anomalies are given by the curves W-L of the surface temperature minus the air temperature in plates 16 to 45.

In many fields there is a good correspondence between the variations of these anomalies and the variations of the surface temperatures and the pressure gradients. This is particularly noticeable in the average curves for the greater southerly region in figures 50 to 52. It appears, for example, that throughout the years with particularly low surface temperature the air is generally much colder than the water, and therefore the difference between the surface temperature and the air temperature is very great. There is, as shown in figures 50 to 52, on the whole a very good agreement of the curve W-L with the curve B, particularly for February, but partially also for the average of January and February.[1]

Consequently the wind must be regarded as the principal direct cause of the observed variations in the winter temperature of the surface of the ocean. At times for example when the wind blows more continuously than usual from the northern directions of the compass, it leads in the first place to colder masses of air being driven southward and consequently the air temperature falls sharply. Later the colder water layers are driven by the wind into the fields covered by our observations.

[1] Notice that in our figures the curves for surface temperature minus air temperature are inverted.

This transportation of cold water-masses from the north toward the south by the wind involves this peculiarity, that the more northerly water-masses are generally in consequence of their lower temperature of a higher density than the southerly and warmer water-masses. The northerly water-masses can theretore not be driven by the wind over the surface of the southern layers, but have a tendency to sink below them though obviously there is a tendency for these layers to mix by the action of the waves. Winds which bring colder water into the region of warmer will therefore not so easily produce considerable variations in the surface temperatures as winds which blow water in the reverse direction from warmer regions toward colder. On the other hand those winds which transport colder water towards warmer regions of the sea have a tendency to produce variations of the temperature in the upper layers of the ocean underneath the surface, since by such winds convection currents are set up in a vertical direction. But they have also the tendency to carry the warmer water-masses of the surface with them toward the south and to replace them with cooler.

THE VARIATIONS IN HEIGHT OF THE WATER OF THE BALTIC SEA AS A PROOF OF THE ACTION OF THE WIND ON THE VARIATIONS OF THE SURFACE TEMPERATURE OF THE NORTH ATLANTIC

That the winds are a strongly contributing cause of the observed variations in the surface temperature in the Atlantic Ocean seems to be shown by the notable agreement between the variations of the temperature condition of the Atlantic Ocean in February and the variations of the average height of the water for the whole year in the North Sea and particularly in the Baltic Sea. We found that if the surface temperature in the Middle Atlantic Ocean in comparison with that on the east shore of the ocean in February was low, then the yearly mean height of the water in the North Sea, particularly in the Baltic Sea, and partially also on the Norwegian coast was high; while if the surface temperature was high in the middle of the Atlantic Ocean in comparison with that at the shore of it the reverse condition was found. That the winds are of importance for this relation cannot be doubted. For we know that the height of the water along the coast depends upon the air pressure distribution and upon the winds, and it is therefore to be assumed that the observed variations in the average height of the water in the North Sea and in the Baltic Sea is brought about in this way. We must therefore logically conclude that the same cause

produces the observed variations in relation between the surface temperature in the middle of the Atlantic Ocean and that of the east shore. To be sure our observations have been assembled for only the coldest part of the winter. We may assume, however, that the relation of this season holds good for other times of the year.

We may well suppose the variations in the average height of the water may also be brought about by variations in the velocity of the currents which are not directly caused by the wind, but even if this less probable assumption should be admitted, it is particularly difficult to explain the variations in the observed relation of the surface temperature in the Atlantic Ocean by such variations in the current velocity. These appear to be naturally explained by the condition of the wind.

However, it may be urged on the other hand that the precipitation over regions draining into the North Sea and the Baltic Sea must be of influence particularly upon the height of the water of the Baltic Sea. But this influence must obviously be of minor importance compared with that of the wind. A hindrance of the outflow of water at the portal of the Baltic Sea in consequence of the wind will obviously be of greater influence on the height of the water within than the greatest reasonable increase of the precipitation which may be imagined, so long as the outflow is not hindered in the Kattegat and in the Belts.

A hindrance to the outflow of water from the Baltic Sea may be thought of in two ways. The winds can cause a rise of the height of the water in the North Sea at the mouth of the Kattegat or the winds in the Kattegat may hold back the water within the Baltic. In both cases there is to be expected a more or less intermittant renewal of the deeper lying waters in the Baltic.

According to the Swedish investigations (see O. Pettersson, 1894, page 532) there was an inflow of salty water from outside in the deeper layers of the Gulmar-fjords at the mouth of the Kattegat in the spring and summer in the years 1890 and 1893. In the year 1899 the ground water in the Gotland-Mulde in the Baltic was renewed (see Krummel, 1907, pages 352 to 353). In the beginning of the year 1903 the ground water in Bornholm Deep and in the Danzig-Mulde was renewed. In the autumm of 1905 the ground water in the Gotland-Mulde and in the Danzig-Mulde was renewed and later in the following year in the Bornholm Deep (Krummel, 1907, p. 301).

In the time between 1890 and 1906 it is exactly in the above mentioned years 1890, 1893, 1899, 1903 and 1905–6, and only in these years that well-marked maxima in the height of the water of the Baltic and the easterly North Sea occurred.

By means of the winds we may explain in a natural way the agreement between the observed relations in the surface temperature in the Atlantic Ocean and the surface temperature at Liepe's station 1 near Ouissant, as well in February as for the whole year, and also the agreement with the temperature in Hamburg in February and partially also with the yearly temperature for Hamburg which we have already referred to.

ARE THE WINDS THE ONLY CAUSE OF THE GREAT VARIATIONS IN THE SURFACE TEMPERATURE?

But even if we admit the conclusion that the winds are a principal cause of a larger proportion of the great variations of the surface temperature within our investigated fields, there is another question whether these variations are alone due to the winds of the locality or its immediate surroundings. The question can for example be put in this way: Are there not beside the variations in the temperature produced by the displacement of masses of water by the wind, also similar changes produced by water-masses which the currents carry along with them?

If this should be the case, then as we have already said, the course of the variations of the values of the surface temperatures minus the air temperature, must be opposite to those which we have found. The transportation of relatively cold water-masses must then cause the surface temperatures of the ocean to come nearer the temperature of the air and the difference between them will consequently be less than usual; and the reverse should happen if the transported water is relatively warm. There arises then the question if variations of this kind are shown in our observations. That appears as we have said above to be the case in a considerable number of instances.

If we observe the temperatures in the single years, it appears that the variations in many cases are not alone due to the local winds. For example, this holds for February as also for March-April, 1904, when the temperature over the greater part of the Atlantic Ocean, particularly over the middle parts, became uncommonly low. The isobars and consequently also the winds at that time over our whole observational region had directions which more or less correspond

to negative anomalies in the surface temperature as our charts, plates 27 and 29, also show. We find, nevertheless, from the curves in figures 48 to 52 that the negative anomalies corresponding to the air pressure gradients in several fields were not so great that they would produce great negative anomalies in the surface temperatures. Furthermore it is also notable that the course of the variations of the curves for the anomalies of the air pressure gradients from field to field in plate 28 is entirely different from the course of the variations of the curves of the anomalies of the surface temperature and the air temperature.

If we take also into consideration that over great regions of the earth not only the temperature of the ocean, but also of the air exhibited considerable negative anomalies (compare what has been said and also the chart pl. 28), we must come to the conclusion that reactions were going on here which were due to other causes than the local winds; more accurately stated, we may conclude that the negative anomalies of the air pressure gradients which we have found over the whole of the investigated region are due to the same causes as the low temperature of the ocean surface and the air over the greatest part of the earth.

If we consider the Dutch material for the two earlier mentioned 10° squares further south, we find that in these two fields the temperatures of the ocean surface was a minimum in February, 1904, while on the other hand the direction and strength of the wind in January to February was not of the kind to bring on such a minimum. It must be remembered however, that the number of observations in these great fields was very small.

We find besides that in a number of stations, particularly in the tropical regions, the temperature of the air for 1904 was uncommonly low and in many places a minimum. As noted by Arctowsky (1912) the reverse of this is found for several regions of the earth. For example, in Honolulu, Bombay, and the most westerly United States there was a maximum of temperature in this year.

This most probably indicates peculiar conditions of the distribution of the air pressure over the earth's surface, which also depended upon general causes. These, however, produced opposite effects both on the air temperature and the water temperature in different regions. As we shall notice later, there appears to have been on the whole a minimum air temperature over the whole earth's surface in the year 1904.

POSSIBILITY OF A DISPLACEMENT OF THE OCEAN CURRENTS

It must be taken into consideration that a fall or rise of the surface temperature in the fields of the North Atlantic Ocean investigated by us is not necessarily a proof of corresponding changes in the temperature of the water-masses which are transported by the ocean currents. It may be that the changes rest merely on a displacement of these masses. The surface layers can for example be driven farther toward the south by the winds and yet at the same time the currents may be more rapid and their temperature in fact as high or even higher than before. In order to get a clearer view of these matters as they progress in the different years, we must have simultaneous records over the surface of the entire Atlantic Ocean and even then it would be difficult to decide if such a displacement actually took place. If we take the years 1899 and 1903 when the wind circulation over the Atlantic Ocean was particularly lively, we might consider that the Gulf Stream drift was displaced further southward. Yet in spite of this it could very well be intensified and consequently the temperature in the water-masses of the Gulf Stream might be raised and this would in its turn produce a rise of temperature in the easterly region of the ocean where these warmer water-masses are carried toward the north.

But consider the year 1904. Very low temperature prevailed over the whole region we have investigated both west and east and can it be believed that the current was again displaced further south? Such an assumption appears to be very difficult to defend, since we find also in the far south fields covered by the Dutch investigations and on the equator itself uncommonly low surface temperatures, and it seems as if the surface of the whole North Atlantic Ocean was in this year particularly low.

INFLUENCE OF WINDS UPON THE AIR TEMPERATURE OVER THE CONTINENTS

By means of our investigations of the influence of air pressure distribution, we have found that the air pressure or the winds have a very great influence on the variations of the surface temperatures of the ocean and also on the temperature of the air, but they cannot be the sole influences affecting these variations. This is shown by the consideration of the variations of the air temperature over the continents on both sides of the Atlantic Ocean.

That the air pressure distribution or the winds have a very great effect on the variations of the air temperature over the continents

is plainly shown by our charts, plates 16 to 41. However, we find also that an apparently similar distribution of air pressure in the same month of different years is consistent with different effects upon the air temperature over Europe. We see, for example, that in the years 1905 and 1907 the air pressure distribution in January-February over the North Atlantic Ocean and the west coast of Europe had the same character, while the temperature distribution over west Europe in February was somewhat different. In February, 1905 (see pl. 30), southwest Europe, Spain, and Portugal had negative temperature anomalies while middle and north Europe had positive anomalies. In February, 1907 (see pl. 34), on the other hand, the temperature anomalies were negative in the whole west, south, and middle Europe and also on the west coast of Africa and northwards to southern Scandinavia. In northern Scandinavia the temperatures were considerably higher than in February, 1905. On the Atlantic coast of America the temperature anomalies were negative in February in both years. These negative anomalies had, however, a greater extension westward in 1905 than in 1907. In March, 1905 and 1907, the temperature conditions over west Europe were quite similar.

The air pressure distribution in the easterly North Atlantic and west Europe are very similar to one another in January and February, 1906 and 1908 (see pls. 32 and 36), with a well-developed tendency to produce cold winds, colder in 1906 than in 1908. But the temperature was opposed and was even very cold in the year 1906 over France, Great Britain, and the Faroe Islands although very warm in the year 1908. Also in Hamburg and Norway it was warm. In January and February, 1907, there were, on the other hand, warm winds over the ocean, but in spite of this, cold temperatures prevailed in February over western, middle, and southern Europe, even colder than in February, 1906. To be sure the winds in January and February on the European coast were weaker and also on the whole more northerly in 1907 than in 1906, but in 1908 (see pl. 36) the pressure distribution was nearly the same as in 1907, and in spite of it the temperature over the coast lands of middle and south Europe was relatively high with positive anomalies. One is inclined to the impression that, as for example in 1907, the air temperature may be made low by special causes and one is led to think of those variations in the solar radiation which were found by pyrheliometric measurements and which indicated a secondary minimum of radiation in 1907. In March, however, unluckily for

this explanation, the temperature relations were again reversed with positive anomalies over western Europe in 1907 and negative anomalies in 1908.

January-February, 1899 and 1903, as also March of 1903, showed the same form of pressure distribution or wind conditions and there prevailed also the same temperature distribution with negative anomalies of the ocean surface and positive anomalies over Europe (see pls. 18, 26, and 27).

January, February, and March, 1904 (see pls. 28 and 29), show similarly practically the same air pressure distribution and wind distribution as 1903 with well-marked negative anomalies of temperature over west Europe in February outside of south and middle Europe, southerly of 50° north latitude. Similar conditions prevailed in the north of Norway in March, and Iceland in March, and partially also in February. This may be compared with March, 1908, when positive anomalies appeared in the ocean in spite of cold winds and negative anomalies over the whole of west Europe, but not over Iceland and northern Norway.

In March, 1905, and in January-February, 1899, there was a well-marked similar form of air pressure distribution as well as of temperature distribution.

If the isobar charts are sufficiently trustworthy for our purposes so that these variations are real (and this we believe) we can think of no other reason for the strong discrepancies in the years when the temperature distribution deviates so far from what would be expected from the condition of the air pressure distribution than that unusual outside conditions have come in play at least over the continents.

There are two causes which may be of importance to influence the temperature of the atmosphere. First, the heat condition of the ocean; second, radiation conditions, such as the solar radiation, the transparency of the atmosphere, and the nocturnal radiation. It may well be that the circulation in the upper parts of the atmosphere, also the vertical circulation of the atmosphere may be of importance, though it seems hardly probable that these should vary so much from year to year when the form of the air pressure distribution over the earth's surface is so similar.

The first named cause, that is to say, the ocean influence, does not appear adequate to produce the deviations in all cases.

VIII. THE SURFACE TEMPERATURE OF THE OCEAN ON THE NORWEGIAN COAST IS DEPENDENT ON THE WINDS

We shall now investigate what influence the winds produce on the surface temperature of the ocean along the coast of the continents, and for this purpose shall employ the series of observations which have been made for a long term of years on the coast of Norway.

Prof. Otto Pettersson and later also Meinardus have assumed that the surface temperature on the Norwegian west coast, at the lighthouses Utsire, Helliso, and Ona, changes with the temperature of the water which is brought by the warm Atlantic current, the Gulf Stream, through the ocean to the Norwegian coast. This appears surprising, for it is well known that the surface water along the Norwegian coast where the observations referred to were made is notably coast water as indicated both by its salt contents and its temperature, and has very little similarity to the water which is carried by the Atlantic Ocean currents on the surface far out in the open ocean.

The coast water is well stratified and the surface is very light on account of its high percentage of fresh water, hence the vertical circulation is greatly hindered, and on this account the yearly temperature amplitude of the thin surface layer is relatively very great, with very few low temperatures in winter and high in summer. It is therefore easy to see that here the winds may produce great temperature variations.

PROBABLE ACTION OF THE WINDS ON THE COAST WATER TEMPERATURE IN WINTER AND SUMMER

During the coldest part of the winter different conditions of the atmosphere would produce the following principal effects on the surface temperature on the Norwegian west coast.

In calm weather, the clouds are generally few and the outgoing radiation consequently is strong with a considerable cooling of the surface particularly in the inner parts of the fjords. On the open ocean, this action is less notable on account of the vertical circulation and because the outgoing radiation is hindered by the foggy air, hence the surface temperature of the ocean increases considerably from the inner parts of the fjords toward the open sea.

When the *winds blow from the land,* there is cold clear weather, strong outgoing radiation and consequently strong tendency to cool the surface. The cold surface water is driven out of the fjords, sea-

wards, and tends to lower the temperature of the coast waters, "Skjargaard." By the land winds the ocean is relatively little disturbed.

When the *winds blow toward the land* the warmer surface water is transported landwards. Since the sea winds on the west coast are relatively warm and attended by increased cloudiness, the outgoing radiation, and therefore the cooling, is diminished. By the wave actions the surface is warmed partly by mixing with underlying warmer water-layers and partly by the exchange of temperature with the air. All these causes tend to increase the surface temperature.

In the warmest season of the year we must, on the other hand, expect exactly the opposite condition of affairs to that which we have detailed. Then the light surface layer of the coast water will be strongly heated and become considerably warmer than the underlying strata and also warmer than the surface water lying further out in the open sea. Accordingly, one must expect with sea winds that the surface temperature of the sea by the lighthouses along the coast, as for example the Ona lighthouse, will fall and that the surface temperatures will rise with land breezes, or when it is calm, so that the surface layer of the coast water shall alone be effective.[1]

RELATION BETWEEN AIR PRESSURE GRADIENTS AND WATER TEMPERATURES AT ONA AND TORUNGEN

We shall first investigate the relation between the surface temperature of the sea at Ona Lighthouse on the Norwegian west coast (where we have a most complete series of observations.) and the winds as determined by the direction of the isobars and the intensity of the pressure gradients. We shall deal with the coldest time of the year, in February, and with the warmest, in August.

In the manner already described, we have determined the direction of the isobars and the intensity of the pressure gradients near Stad at 62° 30′ north, 5° east, and we give their mean direction and intensity by progressive vector diagrams for the eleven-year period 1889 to 1908. In those relating to the coldest time of the

[1] However, land winds may at this time also produce cooling of the surface temperature of the ocean near the coast, because the warmer surface water of the land is driven off and the cooler underlying layers are brought up to the surface, but this occurs generally only for the fjords and the sea nearest the coast. It can for example scarcely occur at an island like Ona, which is much further out to sea.

year, February, we have designated those winds as positive for which the isobars at Stad were directed more towards the land than normal and negative, those in which the direction was more seawards. For the warm part of the year, August, the winds, that is, the isobars, were on the contrary designated negative when they came from the sea and positive when they were more southerly than the mean direction.

By multiplying the sine of the so obtained negative or positive angle between the isobar directions of the single years and the mean isobar direction by the value found for the air pressure gradient, we obtained values given in table 16D and in the curve B of plate 47, figure 2, February.

The curve W for the surface temperatures at Ona Lighthouse in February shows a great similarity to the curve B of the air pressure gradients for Stad in February, which is the full-drawn curve. Still better agreement is shown with the mean for January and February, which is the heavy dotted curve computed according to the expression $\frac{1a+2b}{3}$ (see pl. 47, figure 2, February).

The curve for the surface temperature of Ona Lighthouse for August, which is the full-drawn line of plate 48, figure 2, July-August W, shows also a surprising similarity with the curve of the air pressure gradients for August, which is the full-drawn curve B, and yet better with the curve for the mean of the months July and August, which is the heavy dotted curve B.

The following results which we had expected are confirmed. The temperature of the coast water at Ona varies with the variations of the air pressure gradients, that is to say, the winds, but oppositely in August and February.

We will now investigate the relation between the air pressure distribution and the surface temperature on the Norwegian south coast at Torungen Lighthouse, where the conditions are entirely different from those at Ona Lighthouse. Here the whole sea far from the land is covered to a great extent with coast water, which is transported along the coast by the Baltic current, which at almost all times carries its well-mixed water along by this locality southwestwards. We therefore cannot expect that the local winds would have the same kind of an influence on the surface layers as at Ona Lighthouse, depending on whether they are sea winds or land winds. We should rather expect that the weather conditions would govern the warming or cooling of the coast water or surface water of this

Baltic current and so that the temperature and condition of the atmosphere would play a greater part here than at Ona.

In a preliminary reduction we treated the curves in a similar way to those at Ona, that is, regarded southerly and easterly deviations from the isobars as positive and westerly or northerly deviations as negative. We then found that the variations of the surface temperature at Torungen in February did not agree with the curve for the local wind relation. However, it proved that the easterly wind has a strong tendency to produce lower surface temperatures while the westerly winds tended to produce higher ones. We therefore set a boundary in the isobar directions which ran at from south 10° east to north 10° west. The winds or isobar directions which arise in the region westward of this boundary we regard as positive and those easterly thereof as negative, but in other respects we treat the results in the same manner as above mentioned. Thus we obtained curves for the air pressure gradients which were in very good agreement with the surface temperatures at Torungen Lighthouse in February (see pl. 47, fig. 2, Torungen, curves W and B). The agreement is quite surprisingly good, both as to the curve of the air pressure gradients for February alone (the full-drawn curve B), or still better the mean of the January and February curves computed according to the expression $\frac{1a+2b}{3}$ which is the heavy dotted curve B. We find but one exception to a complete agreement, namely the year 1907, when the surface temperature at Torungen was somewhat lower than it should have been according to the air pressure gradients. Both January and February of this year, however, show depression of the curves.

In the warmest part of the year, July and August, the agreement between the curves for air pressure gradients and the curve for the surface temperature for August at Torungen is not as good, as appears in plate 48, figure 2. This, however, should be expected, because the transported water-masses during this part of the year are able to play so great a part by the warming and cooling of the ocean.

We will now investigate the relations of things in the other months. We find at Torungen a good agreement between the curve of the surface temperature for January and the curve of the air pressure gradients for January (see pl. 47, fig. 1). However, the curve for December shows no similarity, nor does the mean curve of December and January.

The curve of the surface temperature, W, for March at Torungen shows a surprisingly good agreement with the curve of the air pressure gradients for March, (see pl. 48, fig. 1, full-drawn curve B). An even better agreement is shown by the mean between February and March, which is the strong dotted curve B.

In the other months of the year we must expect less close agreement between the curves of air pressure gradients and the curve of surface temperatures because so many other different factors are operating.

We find a tolerable agreement between the curve of the surface temperatures for Ona for January and the curve of the air pressure gradient for Stad for January, but there are exceptions for the several years 1896, 1897, 1904, and 1910. The relation is no better if we take the curve for December (see pl. 47, fig. 1).

The curve of the surface temperature for March at Ona Lighthouse shows remarkably little correspondence with the curve of the air pressure gradients for March. On the other hand, there is a remarkable similarity to the curve of the air pressure gradients for February and also to the mean curve for February and March (see pl. 48. fig. 1). In the other months of the year the agreements between the curves for the variations in the surface temperature and the variations of the air pressure gradients are not so good. For example, in January, there is little similarity between the curves and in the other months there is even less. This depends upon the fact that in these months the relations are more complicated and besides that other conditions come into play. It must be remembered that the conditions of winter and summer are opposed and therefore, in the interval of time between, transition conditions occur.

In our figures, we give also the curves for the surface temperature, W, at Heliso and Utsire lighthouses. The curve for Heliso shows throughout the greatest similarity to the curve for the air pressure gradients for Stad, while the curve for Utsire shows perhaps a greater similarity to the curve of the air pressure gradients for Torungen. But on the whole the results for both stations are such that they form a transition between the curves for Torungen and the curves for Stad and Ona.

RELATION BETWEEN AIR PRESSURE GRADIENTS AND AIR TEMPERATURE AT ONA, TORUNGEN, AND IN ALL NORWAY

We have introduced in our figures curves for the air temperature at Ona, Torungen, and all Norway, as computed from the observa-

tions of 22 meteorological principal stations. These values cover several different months investigated. For the air temperature curves there is a marked agreement with the curves of air pressure gradients. The reader should take notice that the temperature scale is twice as great for the water curves W, as for the air curves, L.

For January, February, and March, the curve for Torungen, that for all Norway, and in part that for Ona show greater agreement with the corresponding air pressure curves for Torungen than with the curves for Stad, but there is great similarity to those for both. In January the curves of air temperature for Ona and for all Norway show a great similarity (see pl. 47, fig. 1L, Ona, and L, Norway). These two curves show certain agreement with the air pressure gradient curves B for Stad and for Torungen.

In February the curve for air temperature for Ona agrees better with the curve for air pressure gradients for Torungen than for Stad. This is particularly noticeable in the year 1901 and also in 1910 when the curve for surface temperature for Ona has a quite different run in comparison with the air pressure curve for Stad. The air temperature curves for Torungen and for all Norway are quite similar to the air temperature curve for Ona and agree very well with the air pressure curves for Torungen. As an example of a characteristic common to all three temperature curves, see for instance the rise of the years 1900 to 1903. This rise we find also in the curve of the air pressure gradients for Torungen, and not only for February but also for the mean between January and February, but not for the air pressure curve for Ona for the month of February, which gives a marked maximum in the year 1901. This shows itself more strongly in the curve of surface temperatures for Ona than in the curve of air temperature. The explanation is plainly this: The winds as indicated by the isobars for February in this year had a strong northerly direction at Stad and at Ona Lighthouse and came from the ice ocean. It was a sea wind, which caused the rise of the surface temperature at Ona, but at the same time cold winds blew over Norway and the air temperature in February as well at Ona and Torungen as also in all Norway was relatively lower. These strong northerly winds appeared meanwhile not particularly favorable for the rise of the surface temperature at Heliso or Utsire, and least so at Torungen where the curves show no rise corresponding to the maximum which we find at Ona.

In March the curve of air temperature at Ona shows no very good agreement with the curves of air pressure gradients either for Stad

or for Torungen. The curves for air temperature at Torungen and for all Norway show generally a similarity with the curve of the air pressure gradients for Torungen for the month of March, but there are nevertheless many disagreements, as shown in figure 1 on plate 48.

For August, the air temperature curve for Ona and all Norway shows agreement with the air pressure curves of August and the mean of July and August for Stad.

AGREEMENT BETWEEN THE TEMPERATURE VARIATIONS IN THE COAST WATER AND IN THE AIR OVER SCANDINAVIA, BOTH DETERMINED BY AIR PRESSURE DISTRIBUTION

From what has gone before, we can conclude with certainty that the variations in the air pressure distribution control not only the surface temperature on the Norwegian coast, as at Ona and Torungen, but also the air temperature in Norway during the coldest and warmest part of the year. Since the air pressure distribution (wind) has a simultaneous action upon the temperature of the coast water and the temperature of the land, we can expect that both these temperatures would follow in such a sequence that the characteristic variations would be a little earlier in the air than in the water. Such an agreement cannot be merely local but must be shown over great regions, because the air pressure distribution has a very extended sphere of influence. If, for example, the temperature variations for all Norway are compared with those in Stockholm, we find a complete agreement. We shall later return to the consideration of such comparisons (see fig. 75).

In order to examine these correlations more carefully we have made a comparative investigation of the temperature variations of the Norwegian lighthouse stations, Torungen, Utsire, Heliso, and Ona, and the temperature variations at so far removed a locality as Stockholm. The results are given in figure 53. The pairs of curves A show the variations of the temperature deviations from month to month for 37 years, 1874 to 1910. From the monthly values we have computed consecutive 12-month means as shown in curves B, and from the latter also 24-month means, as shown in curves C, in order to bring out periodic phenomena. The sun spot curve, S, is introduced lowest in the figure. The temperature scale is twice as great for the coast water, which has the scale on the right hand, as for the air with the scale on the left, because the variations of the air temperature are greater than those of the

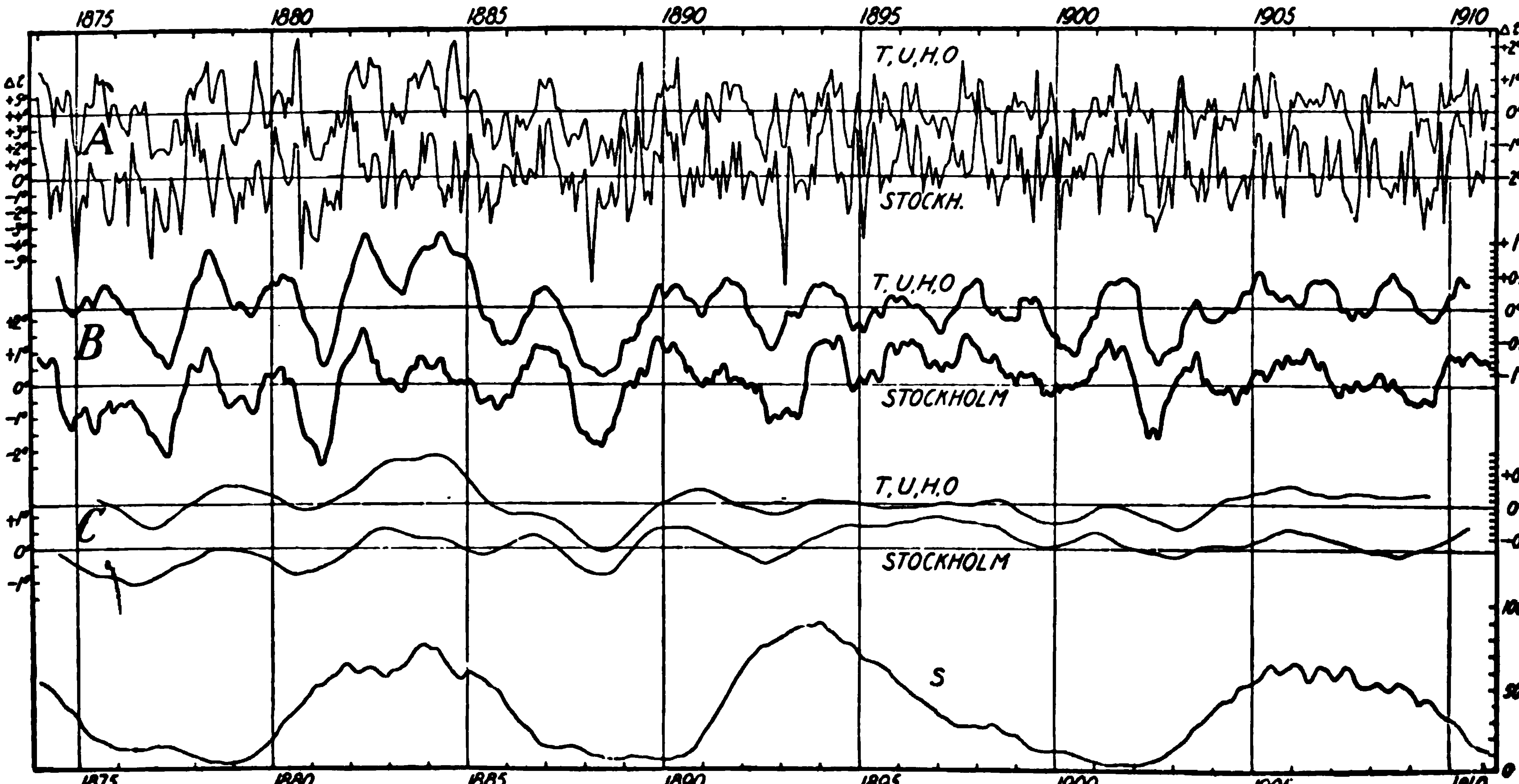

FIGURE 53. Curves for the anomalies of the surface temperature on the Norwegian coast. The letters T. U. H. O. represent Torungun, Utsire, Heliso, and Ona. Also the air temperature in Stockholm. A: simple monthly mean. B: the monthly mean with consecutive twelve-monthly smoothing. C: the same with consecutive twenty-four monthly smoothing. S: the sun spot relative numbers in twelve-monthly consecutive smoothing.

surface temperature. The variations show a good agreement with one another. From the zigzag curve A one sees that the agreement descends even to the smallest peculiarities. For instance, see how quickly the variations follow one another in 1889, 1894 to 1895, 1899, and so on, with almost complete parallelism. There is to be sure a small displacement between the curves oftentimes, so that strong maxima or minima show a tendency to appear earlier in the air in Stockholm than in the Norwegian coast water. This may be estimated as some days or even a couple of weeks, and shows itself very frequently in the monthly means we have employed. The reverse and earlier coming of the extreme in the water than in the air is found only exceptionally. In the curves B and C, which we compare, one finds a well-marked parallelism, with a similar tendency to displacement to that shown also in the A curves. In the C curves, where periodic variations of two years or rational parts of it are eliminated, and principally only the longer periods can come to observation, the displacement is, however, shown quite distinctly. The maxima and minima fall in most cases earlier in the curve for Stockholm than in that for the Norwegian lighthouse stations.

From the nearly simultaneous occurrence and well-marked agreement of the features of these curves, it follows with great certainty that no causal relation exists between the variation of the surface temperature on the Norwegian coast and the variations of the air temperature in Scandinavia, but rather that both variations must be due to the same cause, although the action takes place a little earlier in the air than in the coast water.

The direct common cause of short interval variations is, according to our view, doubtless the variation in the air pressure distribution, which is rendered very probable by the above described investigations on the relation between the air pressure distribution and the surface temperature at Ona and Torungen. We shall later speak of a yet more elegant proof of the accuracy of this assumption.

Accordingly it is clear that the surface temperature on the Norwegian coast cannot be used as a measure of the temperature variations of the water-masses of the warm Atlantic ocean currents in the North Sea, as has been done by Pettersson and Meinardus. In this connection it is interesting to remark that Pettersson found the best agreement between the surface temperature on the Norwegian coast and the air temperature in Sweden in February, and not so good in January. This corresponds exactly to what we have found,

that the variations in the surface temperature at Ona, and the other Norwegian lighthouse stations in February are in closer agreement with the variations of the wind conditions than in January.

IX. THE PERIODICITY OF THE VARIATIONS OF THE SURFACE TEMPERATURE OF THE ATLANTIC OCEAN AND OF THE AIR TEMPERATURE OF THE CONTINENTS

If we now go on to the investigation of the possible causes of these variations, it is obviously necessary to investigate whether they are entirely aperiodic or are in some way arranged in determined periods which can be recognized.

Unfortunately the series of observational material which was available to us for the Atlantic Ocean is too short in order to study the periods by the general methods of harmonic analysis. However, we have endeavored to get an approximate analysis out of the mean temperatures which we have found for the whole investigated path across the North Atlantic Ocean for the series of years 1898 to 1910.

The table following figure 29 shows the observed anomalies of mean surface temperatures in all of the regions investigated by us of the North Atlantic Ocean between America and Europe. We have not employed the Danish fields north of 50° north latitude We have compared these values in different ways corresponding to the periods we wish to eliminate. The elimination was performed in the ordinary manner according to the formula: $X=\frac{a_1+\ldots+a_n}{n}$. We have eliminated first a two-year period, then a three-year period and finally a five-year period.

The results are given graphically in figure 54. The curve *a* shows the orginally found anomalies of the mean temperature. The curves *b*, *c*, and *d* show the values after elimination of the two- three- and five-year periods. In the two latter curves (*c* and *d*) we give the results after the elimination of the short periods by full-drawn lines. The dotted line *c* shows the result of the three years' elimination as obtained directly from the observed values shown in curve *a* without regard to the two years' elimination. In the same way is shown by the dotted line *d* the result for the five years' comparison directly from the original values. The curve *d* has a very regular march. The dotted curve extends over eight years. The residual values which this curve yield may indicate periods of longer duration. One naturally thinks first of the eleven-year sun spot period and the

Bruckner period. Curve *e* shows a small part of the possible Bruckner period. In case the hypothetical values which may be found from this curve should be eliminated from the values which are given in curve *d*, one would obtain the values given in curve *f*. By means of the different eliminations, the amplitude of the different changes

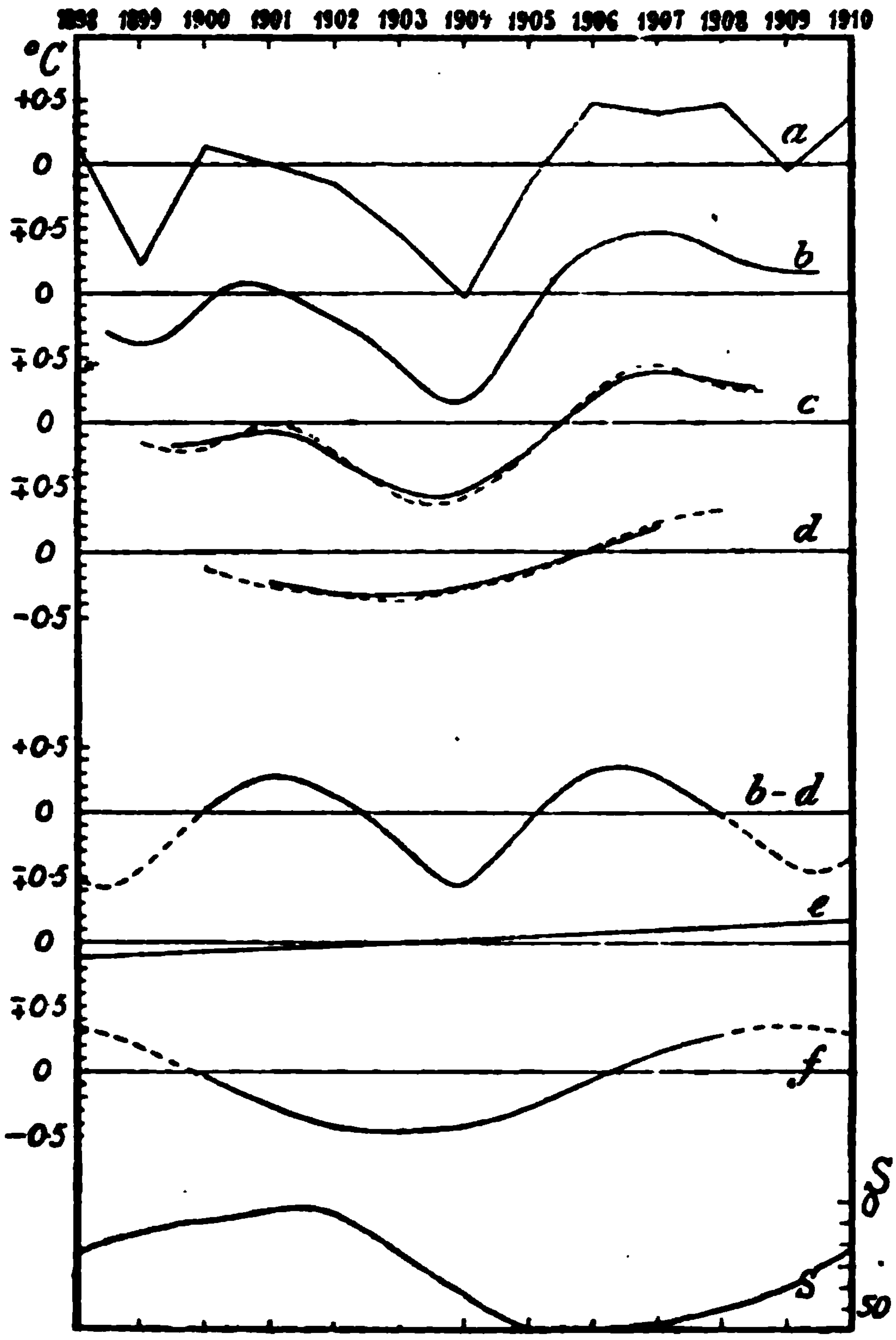

FIGURE 54. The mean temperature of the North Atlantic Ocean Channel to New York, for February (a) according to the two-year (b), three-year (c), and five-year smoothing (d). b-d: curve for the difference between b and d. e: curve of the possible Buckner period. f: the value of the curve. d: after elimination of the curve e. S: the inverted sun spot curve.

is somewhat diminished and in the construction of the curve *f* on figure 54 we have taken account of this reduction and have employed the values ($f=\frac{10}{7}d-e$) which are found according to Schreiber's formula (see Wallen, 1913). It seems proper to regard this curve as a part of the sun spot period and accordingly one may produce the curve as the dotted line shows, thus obtaining a regular curve in which the difference between two succeeding maxima amounts to

eleven years. The sun spot curve itself is given below in figure 8 but inverted.

The two-year period is of small importance for the temperature of the North Atlantic Ocean. It is inconceivable but that periods of so short an interval must entirely disappear in that great region, for they would be found in different places in consequence of different climatic conditions. The three-year period is more strongly brought out, but the period of five or five and a half years is particularly marked. This is the half of the sun spot period and is shown by the curve *b-d*. This is obtained with the help of the difference between the values which are given in the curves *b* and *d* and therefore relates alone to the five-year period.

It may appear arbitrary to assume that real periods for temperature variations at the surface of the Atlantic Ocean can exist, but such periods obviously need not be primarily for the surface temperature of the ocean, but can be called forth by the same causes as for example periods in the air pressure distribution. However, as we have before said, our series of observations is all too short to draw certain conclusions with regard to the matter.

It is to be noted that in the above analysis we have used only observations of February, but as stated already it appears as if the temperature of the surface of the Altantic Ocean in February is significant of the whole year and the changes which we observe then closely represent the changes for the whole year. In other parts of the Atlantic Ocean we have carried on the investigations for each month in the whole year for about the same period of time, which we have treated above. This has been done for the Danish fields north of 50° north latitude and by the aid of the International Central Bureau in Copenhagen, tables of monthly mean temperatures for the period 1900 to 1913 have been obtained for three fields in the southerly North Atlantic Ocean between 36° and 37° north, between 20° and 21° north, and between 0° and 1° north.

In figure 55 we give yearly curves for the four northerly Danish fields (see curves I to IV), as well as curves for the three fields of the Central Bureau (curves V to VII) according to the results of twelve-month consecutive means.

We find here the same opposition that we have earlier called attention to between the curve for the easterly Danish field 0° to 9° west longitude (curve I) and the curves for the westerly Danish fields 20° to 29° west longitude and 30° to 39° west longitude,

further out in the Atlantic Ocean (see curves III and IV). The curve I shows a tendency to an opposite march compared with the latter curves, while curve II for the intermediately lying 10° longitude field shows a transition between the two types. Of the curves

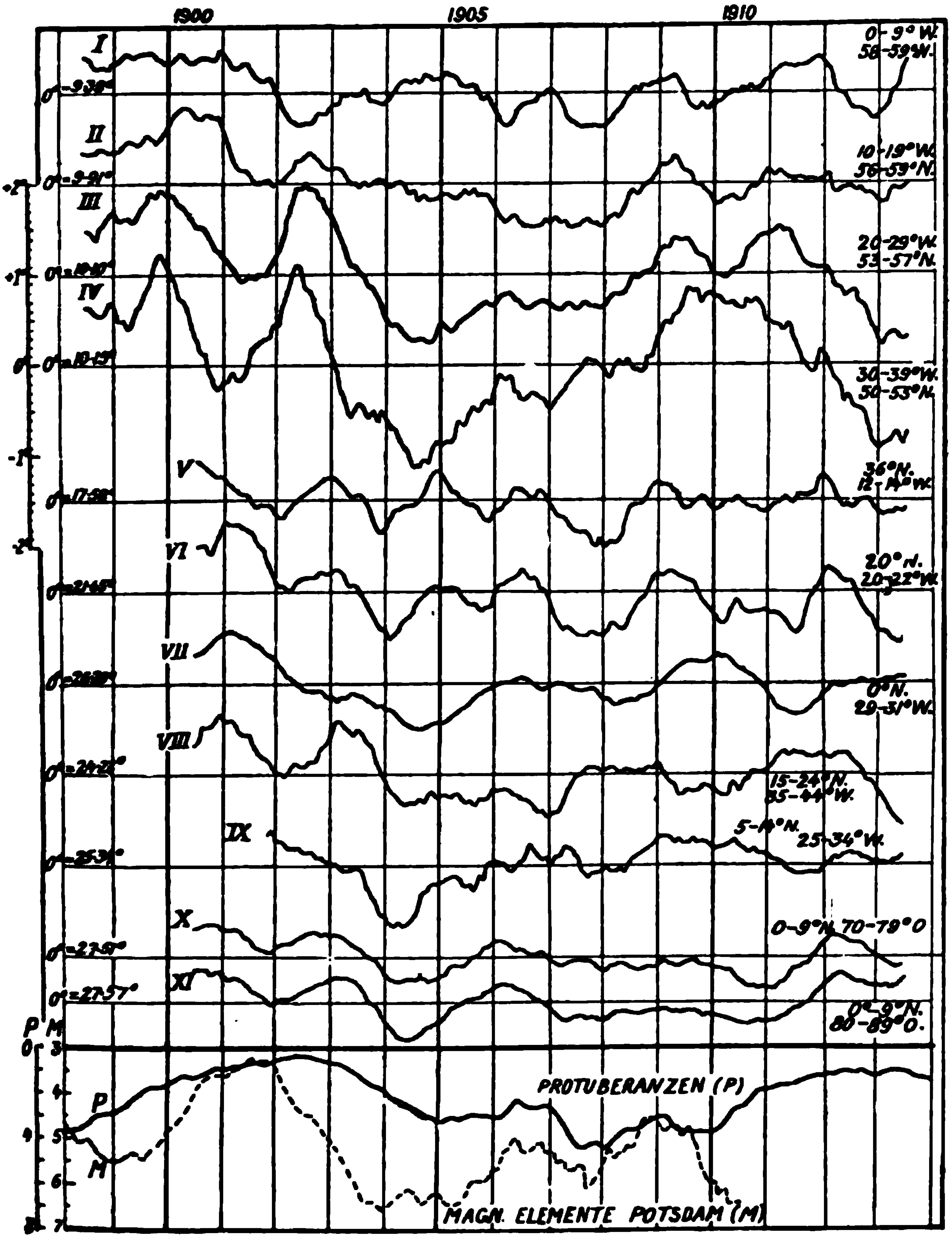

FIGURE 55. The temperature curves smoothed by twelve-month consecutive means for the Danish fields (I to IV), for the three fields from the Central Bureau (V to VII), for the Dutch 10° squares in the Atlantic (VIII to IX), and in the Indian Ocean (X to XI). The inverted prominence curve (P) is given according to the observations in Palermo and Catania (the scale for P is on the left). M gives the character value for the degree of disturbance of the three magnetic elements in Potsdam with the scale at the right.

for the three southerly fields, curve V, the most northerly of them, near the Portuguese coast, has most similarity to curve I, while curve VII for the field on the equator more in the middle of the Atlantic Ocean, shows, as was to be expected, more similarity to curves III and IV.

In figure 55, we give the curves for the year temperature by consecutive twelve-monthly means which were earlier obtained for the Dutch 10° squares in the Atlantic Ocean at 15° to 24° north latitude and 35° to 44° west longitude, 5° to 14° north latitude, 25° to 34° west longitude (see curves VIII and IX), and in the Indian Ocean 0° to 9° north latitude, 70° to 79° east longitude, 0° to 9° north latitude, 80° to 89° east longitude (see curve X and XI.).[1] Curve IX has, as was to be expected, much similarity to curve VII for the field on the equator. The two curves X and XI for the Indian Ocean have also much similarity to the Atlantic tropical curves. On the other hand the curve VII for the most northwesterly Dutch field, at 15° to 24° north latitude and 35° to 44° west longitude, has a more mixed character. The first part, up to the years 1905 or 1906, bears much similarity to curves V and VI and also with the curves X and XI of the Indian Ocean, while the last part has less similarity with the other curves and goes in part opposite to the more equatorial curves VII and IX.

It has been shown that the monthly temperature values for Petersen's single stations in the Atlantic Ocean along the route Channel to New York can not be regarded as entirely trustworthy, particularly in the western part of the ocean. If, however, we employ the temperatures of the eastern stations east of 47° west longitude, (see fig. 13) and the monthly means for two and three stations combined, it is to be expected that we shall obtain comparatively trustworthy values, particularly if we take twelve-monthly consecutive means. The temperatures in this part of the ocean, particularly in the most easterly parts, east of 40° west longitude, are indeed comparatively uniform over great stretches. The four curves, P VII-VIII and P I-II of figure 56 give the values obtained in this way for successive twelve-monthly consecutive temperature means

[1] As mentioned already, the values found for the temperature for these Dutch fields in the Atlantic Ocean are not very trustworthy since the fields are too great and the observations for each month often very few. In spite of this one may perhaps hope that the worst inaccuracies are eliminated in the twelve-monthly means. The temperature values for the two fields in the Indian Ocean are better, for the observations are much more numerous and the relations are very similar.

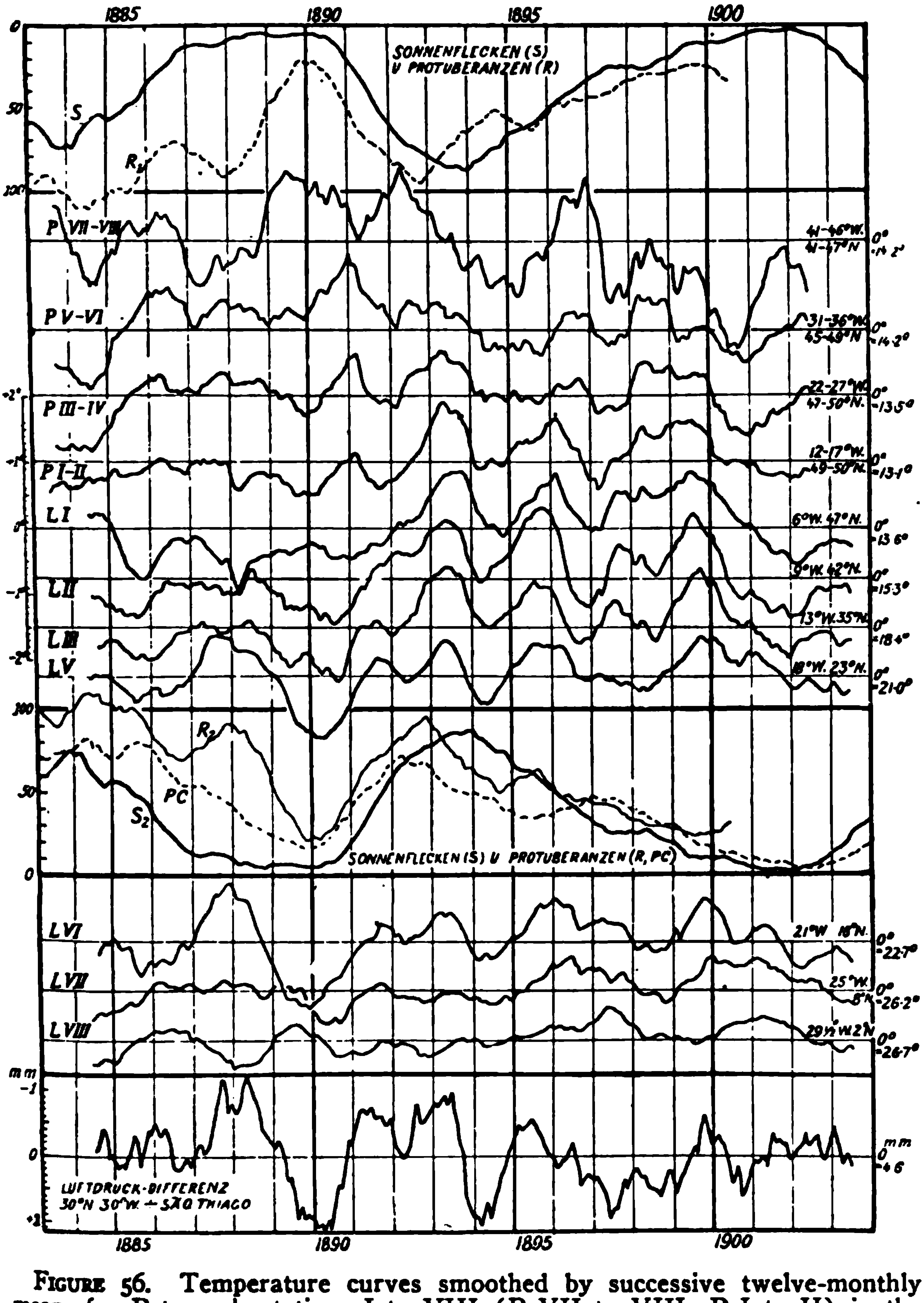

FIGURE 56. Temperature curves smoothed by successive twelve-monthly means for Petersen's stations I to VIII (P VII to VIII- P I to II) in the North Atlantic in the shipping course Channel to New York and for Liepe's stations I to VIII (L I-L VIII) in the North Atlantic between 48° north and 2° north. S_1 R_1: the inverted curves for sun spots and prominences according to the observations at the Osservatoria del Collegio Romano. S_2, R_2: the same curves direct. PC, the prominences according to the observations in Palermo and Catania. At the bottom is given the inverted curve for the difference of air pressure between 30° north latitude 30° west longitude and Sao Thiago (Cape Verde Islands).

for Petersen's stations VIII and VII combined (curve PVII-VIII); Stations VI and V (PV, VI); stations IV and III (P III and IV) and stations II and I (PI, II). We give the corresponding curves for Liepe's stations, I, II, III, V-VII (see curves L.I to L.VIII).

We see that the curves for Petersen's stations agree well together. The greatest disagreement we find in curves P VII-VIII for stations VIII and VII the two most westerly of the stations, used where it would be expected since the isotherms lie so near together. Elsewhere one finds a gradual transition in these curves from west towards east, and then a further transition from the curve PI II, for Petersen's most easterly stations II and I to the curves for Liepe's stations I and II (curves LI, LII) and further southward.

The development in these curves is so gradual that without having noticed the transition a type is obtained in the curves L-III, L-V and L-VI which in its principal features is opposite to the type of the curves P-VII to P-VIII and P-V to P-VI. To a great extent we find maxima in the last curves as opposed to minima in the first. It is exactly the same opposition which we have already several times mentioned between the temperature variations in the middle parts of the North Atlantic Ocean (P-VII-VIII, P-V-VI, L-VII, L-VIII) and in the most eastern parts of it (curves L-I, L-VI). We see here that this eastern effect stretches southwards at least up to Liepe's stations VI at 18° north latitude, between Africa and the Cape Verde Islands.

All these curves in figures 55 and 56 show good agreement in the temperature variations which prevail on the one side over wide stretches of the Middle Atlantic Ocean and also of the Indian Ocean, and on the other side over wide stretches of the most easterly part of the Atlantic Ocean between the tropics and 60° north latitude.

Our figure 56 shows still more. The curves for the middle part of the ocean (curves P-VII-VIII, P-III-VI, L-VII, L-VIII) have in part similarity to the inverted curves of sun spots and prominences (curves S_1 and R_1, at the top of the figure) while the curves for the most easterly part of the ocean, particularly the curves L-II and L-IV show more similarity to the direct curves of sun spots and prominences (curves S_2, R_2 and PC).

As one may see, there is in these different curves an indication of a two-year period (see fig. 55, curves I, V, VI; fig. 56, curves

P-I-II, L-II to L-V) and a three-year period (see particularly fig. 55, curves III, IV, and VII to IV; fig. 56, curves P-VII, VIII, P-III-IV). These three-year periods agree with the corresponding periods of the prominences quite definitely. See for example in figure 56, curves L-V and L-VI compared with R_2 for the prominences, as obtained by the Osservatorio del Collegio Romano. As we have mentioned above, the curves show a certain similarity to the sun spot curve which points toward an eleven-year period. In order to bring these periods distinctly to view, we have taken the yearly means for the calendar years of temperature

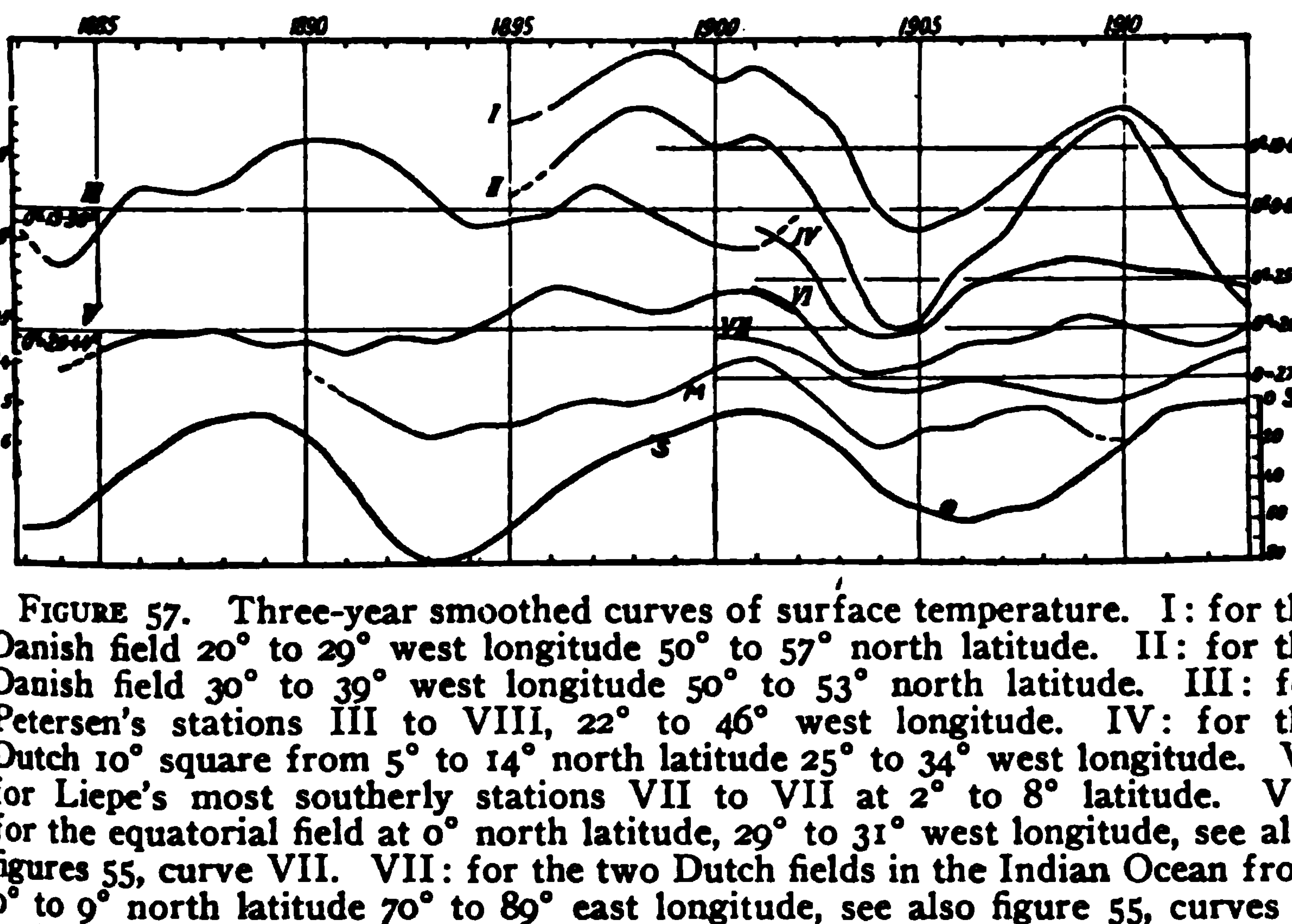

FIGURE 57. Three-year smoothed curves of surface temperature. I: for the Danish field 20° to 29° west longitude 50° to 57° north latitude. II: for the Danish field 30° to 39° west longitude 50° to 53° north latitude. III: for Petersen's stations III to VIII, 22° to 46° west longitude. IV: for the Dutch 10° square from 5° to 14° north latitude 25° to 34° west longitude. V: for Liepe's most southerly stations VII to VII at 2° to 8° latitude. VI: for the equatorial field at 0° north latitude, 29° to 31° west longitude, see also figures 55, curve VII. VII: for the two Dutch fields in the Indian Ocean from 0° to 9° north latitude 70° to 89° east longitude, see also figure 55, curves X and XI. M: for the degree of disturbance of the three magnetic elements in Potsdam. This curve is given with its scale at the left and the curve inverted. S: for the relative sun spot numbers. This curve is given with its scale on the right, curve inverted.

for the different fields and have subjected them to three-years' smoothing.

In figure 57 we give in graphical form the results obtained in this way for temperature values of fields in the middle part of the North Atlantic. These include the Danish fields 20° to 29° west longitude and 30° to 39° west longitude, curves I and II; Petersen's stations III to VIII combined into one curve III; the Dutch 10° squares at 5° to 14° north latitude and 25° to 34° west longitude, curve IV; Liepe's stations VII-VIII, shown in curve V; the equatorial field of the International Central Bureau 0° north latitude, 29°

to 31° west longitude, shown in curve VI. Finally we give a similar curve VII for the two Dutch 10° squares in the Indian Ocean combined. At the bottom of the figure is shown a curve S for the sun spot relative numbers and the curve M for the degree of disturbance of the three magnetic elements in Potsdam (characteristic mean according to Eschenhagen's system). The values of curves S and M are obtained by three years' smoothing and the curves are inverted.

On the whole these temperatures curves, I to VII, give unquestionable agreement with the sun spot curve though with some irregularities. The curve III and curve II combined show the two sun spot periods between the sun spot maxima in 1883 and 1905. This is the case with the combined curve V and VI. The minima and maxima of these curves do not coincide, however, exactly with the maxima and minima of the sun spots, but come a little later, see for instance the years 1884, 1890 and 1894. Sometimes earlier, as in the years 1904-5, 1909-10, and also the minimum of curve V in the year 1891. The curve III has a depression in the years 1899 to 1901 when it was sun spot minimum, while the curves II and I have very well marked maxima in these years.

The curves we have compared (see figs. 21 and 22) for the 10° longitude fields of the route Channel to New York show a phase displacement of the temperature minimum and also of the maximum, particularly in February, so that the minimum and maximum occur earlier in the western part of the ocean between 50° and 60° west longitude, than further east at 20° to 29° west longitude. A similar displacement of the minimum and also of the second maximum is shown by the smoothed I, II, IV, and VI, figure 57. The minimum and maximum are found earlier on the equator (curve VI) than further north (see curves IV, II and I). Such a displacement of the minimum and of the maximum is, however, not to be seen on the consecutive twelve-monthly smoothed curves III, IV, VII, and IX of figure 55.

The Atlantic temperature curves, particularly IV and VI, have also the same character as the curve VII for the Indian Ocean, only that this latter shows very low temperature values in the year 1909 and 1910. By comparing the Atlantic curves I, II, IV, and VI with the inverted sun spot curve S, of figure 57, one sees that the temperature minima are one or two years before the sun spot maximum, and the temperature maximum of 1909 and 1910 was even as much as two or three years before the sun spot minimum. However, as regards the minima, the temperature curves I, II, IV

and VI show better agreement with the magnetic curve M. On the other hand, as already remarked the minima of curve III fell in the years 1884 and 1894 a year after the sun spot maxima and the maximum in the year 1890, a year after the sun spot minimum. These yearly temperature curves I, II, IV, and VI show also undoubted similarity to curve *f* of figure 54. There appears, however, to be some phase displacement, but this may be due to some special accidental causes.

The curves of the eastern fields of the Atlantic Ocean show at least in part, as already remarked, a direct similarity with the sun spot curve. We have computed the mean of the temperature value for Liepe's stations I, II and III and have carried through a three years' smoothing of the observations. The temperatures

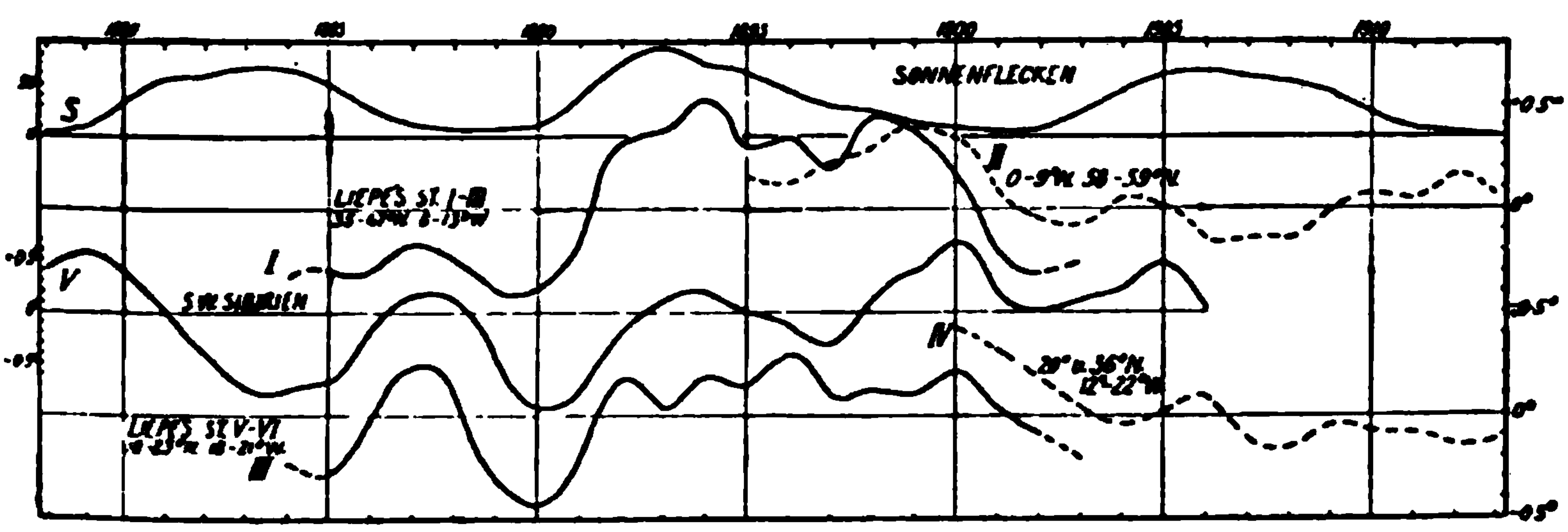

FIGURE 58. Three-year smoothed curves of surface temperature. I: for Liepe's stations I to III. II: for the most easterly Danish field from 0° to 9° west longitude 58° to 59° north latitude. III for Liepe's stations V and VI. IV: the two most northerly fields from the Central Bureau at 30° and 36° north latitude, see also figure 55, curves V and VI. V: for the air temperature in southwest Siberia. S: curve of the vertical sunspot numbers with the scale on the left.

for his stations V and VI, have been treated in the same way. The results given in curves I and III of figure 58, curves II and IV representing the temperatures of the Danish fields 0° to 9° west longitude 50° to 59° north latitude are similarly obtained, and the two fields of the Central Bureau, at 36° north latitude and 20° north latitude (see fig. 55, curves V and VI) and finally curve V for the air temperature in southwest Siberia are also given. Above is the curve S for the sun spot numbers.

During the sun spot period 1889 to 1901, the smoothed temperature curves I to IV show quite good agreement with the sun spot curves, except that the temperature curves I and III show four shorter periods within this long period. In the next sun spot period, after 1901, curves II and IV have a tendency to go opposite to the

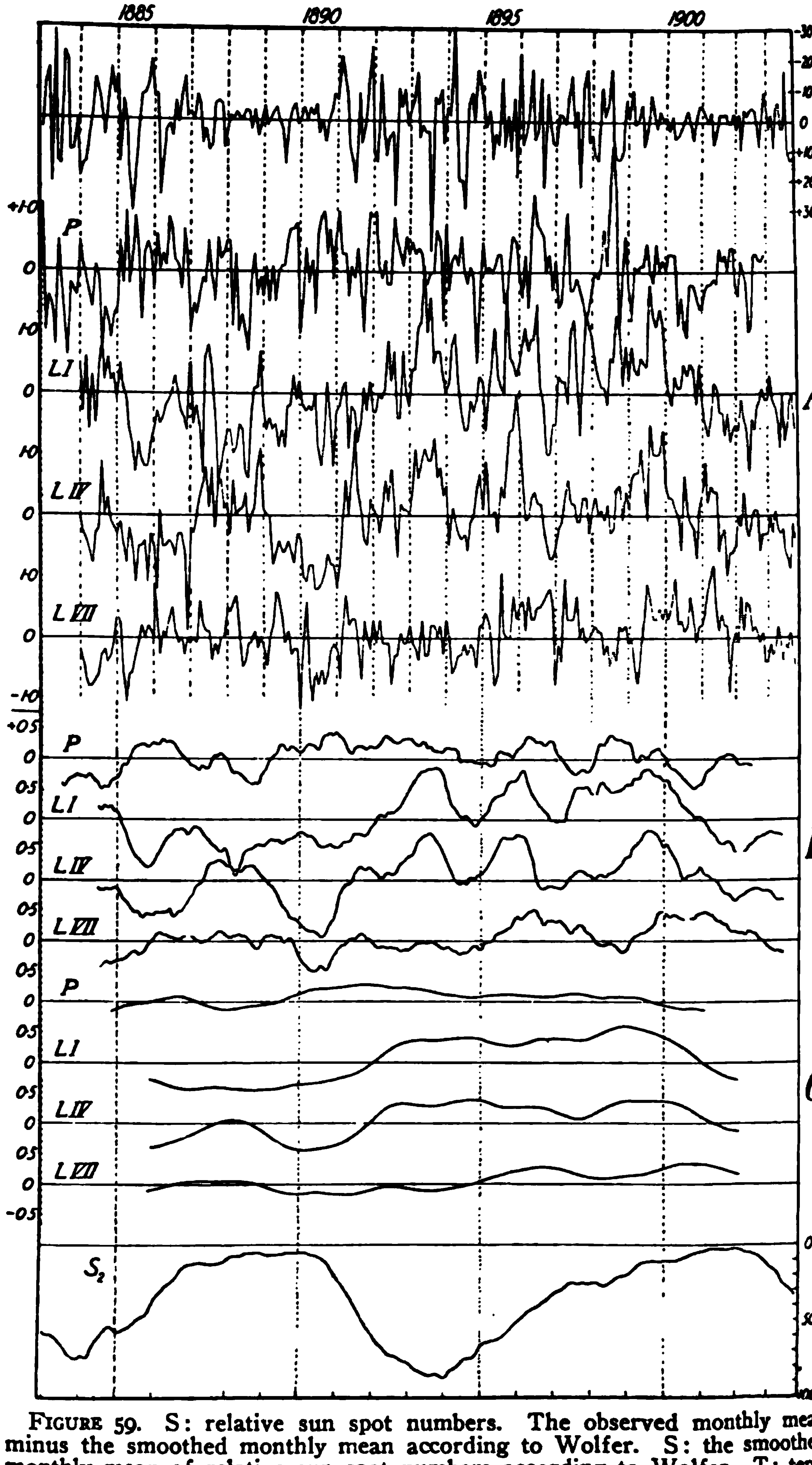

FIGURE 59. S: relative sun spot numbers. The observed monthly mean minus the smoothed monthly mean according to Wolfer. S: the smoothed monthly mean of relative sun spot numbers according to Wolfer. T: temperature curve for Petersen's combined twelve stations Channel to New York. LI, LIV, LVII: temperature curves for Liepe's stations I, IV, and VII at 47°, 30° and 8° north latitude, 6°, 15° and 35° west longitude. A: the monthly anomalies of the observed temperature values. B: the same with twelve-monthly smoothing from values A. C: the same with thirty-three monthly smoothing from values B.

sun spot curve, particularly curve II, but in this period also are included three or four shorter periods.

The direct agreement between the temperature curves for the eastern part of the North Atlantic and the sun spot curves is shown in figure 59. Curves C were obtained by taking consecutive thirty-three month means of the temperature values. The short periods are thus to a great extent eliminated. These curves for Liepe's stations I and IV (L-I and L-IV) show a distinct agreement with the sun spot curve S_2 which is the lowest of the figure, only it is to be observed that this curve is inverted. The two temperature curves have minima at sun spot minima and high temperatures at sun spot maximum in the years 1893 and 1894. In addition the corresponding curves B for L-I and L-IV show a strongly marked division of the sun spot period in three or four shorter periods similar to those of the prominences.

It seems clear that in the surface temperature of the Atlantic Ocean several periods occur for which one of about three years is particularly notable and also a longer period which corresponds with the sun spot period. The temperatures vary in these periods in the middle part of the ocean oppositely to the sun spot numbers, while in the eastern parts they increase more or less directly. As it has repeatedly been remarked, our observational series is all too short in order to give certain conclusions with regard to these matters. Considerably longer are the observational series of Petersen and Liepe, but they are not sufficient, and still longer series of ocean temperatures are unfortunately not available. In the lack of sufficiently extensive observational material in the ocean and because we have found great agreement in general between the condition of the ocean and of the air, we have undertaken to investigate the various meteorological elements which have the advantage of having been published for a long period of years.

We will first compare the variations in the surface temperature of the Atlantic Ocean found by us with the variations of the air temperature in different regions of the earth for the period of years 1898 to 1910. Such a comparison is given in figures 60 and 61. Curves I to IV in these two figures show the variations in the air temperature in different regions according to Mielke's tables (1913) given in Köppen's investigation of 1914. The other curves show the variations in the surface temperature in the different parts of the Atlantic Ocean partly for the whole year, partly only for the month of February.

In figure 60 one may see that the curves for the temperature variations both for the whole Atlantic Ocean and for the middle part of it have great similarity to the curves of variation of air temperature in the tropics and in the south temperate zone, also for the whole earth and in part a similarity to those of North America.

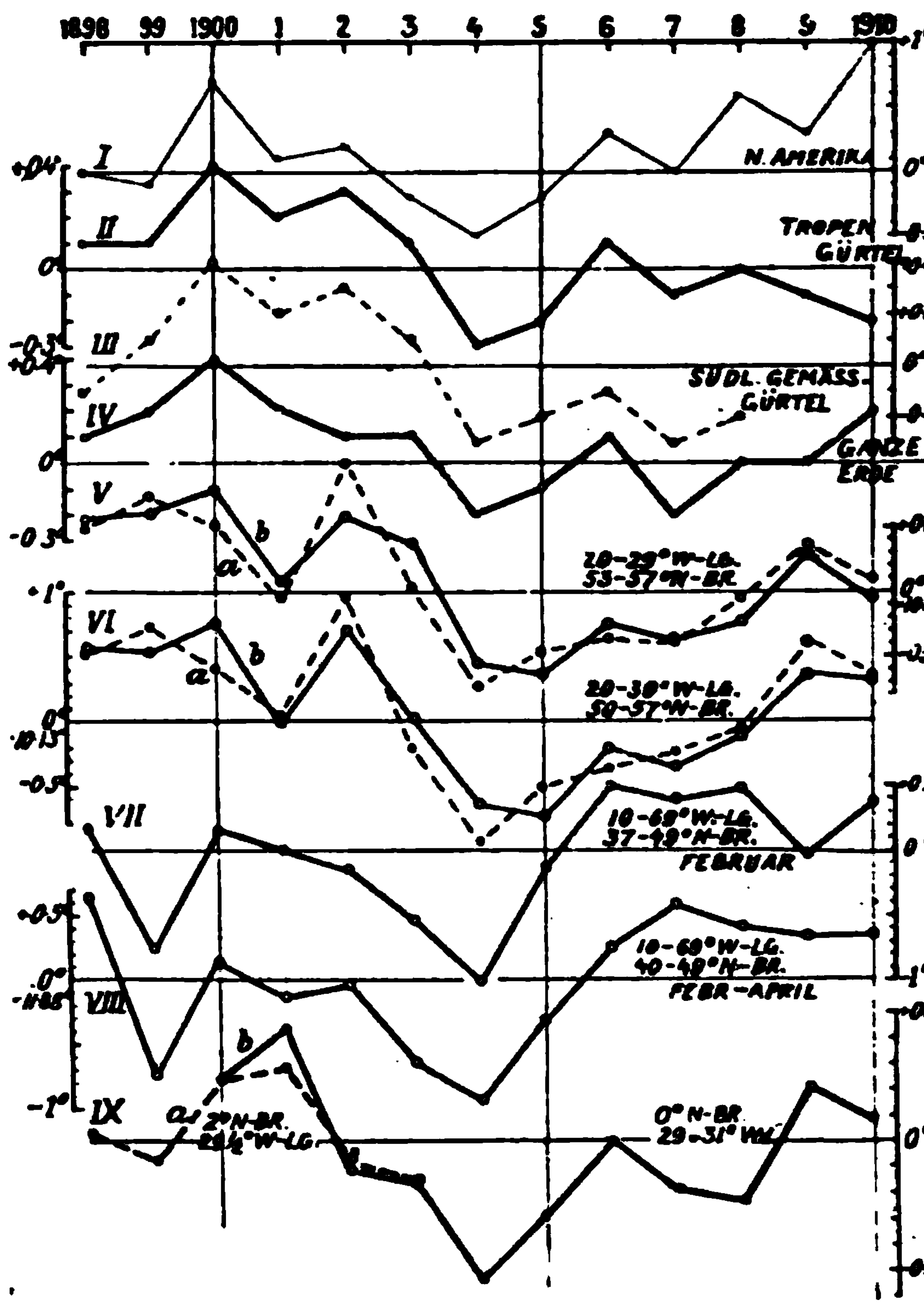

FIGURE 60. Curves for the yearly anomalies of air temperature according to Mielke in North America, the Tropics, Southern Temperate Zone, the whole earth (I to IV), the surface temperature in the Danish field 20° to 29° west longitude, and in the two Danish fields 20° to 29° west longitude and 30° and 39° west longitude (VI, *a* for the calendar year, *b* for September to August), in the equatorial field of the Central Bureau (IX*b*), and at Liepe's station VIII (IX*a*). The temperature anomalies of the surface along the route Channel New York in February (VII), and February-April (VIII).

This similarity to the yearly variations of air temperature holds for the surface temperature, both for the whole year, as shown in curves V, VI, and IX, and for February, shown in curve VII, and also for February to April, curve VIII.

Figure 61 shows great similarity between the curves for the variation in the surface temperature in the *eastern part* of the Atlantic

Ocean both for the whole year (curves V, VI, and IX) and for the month of February (curve VII) with the curves for the variation of the yearly temperature of the air in the north temperate zone in Eurasia and to a certain degree also in western middle Europe and in Russia.

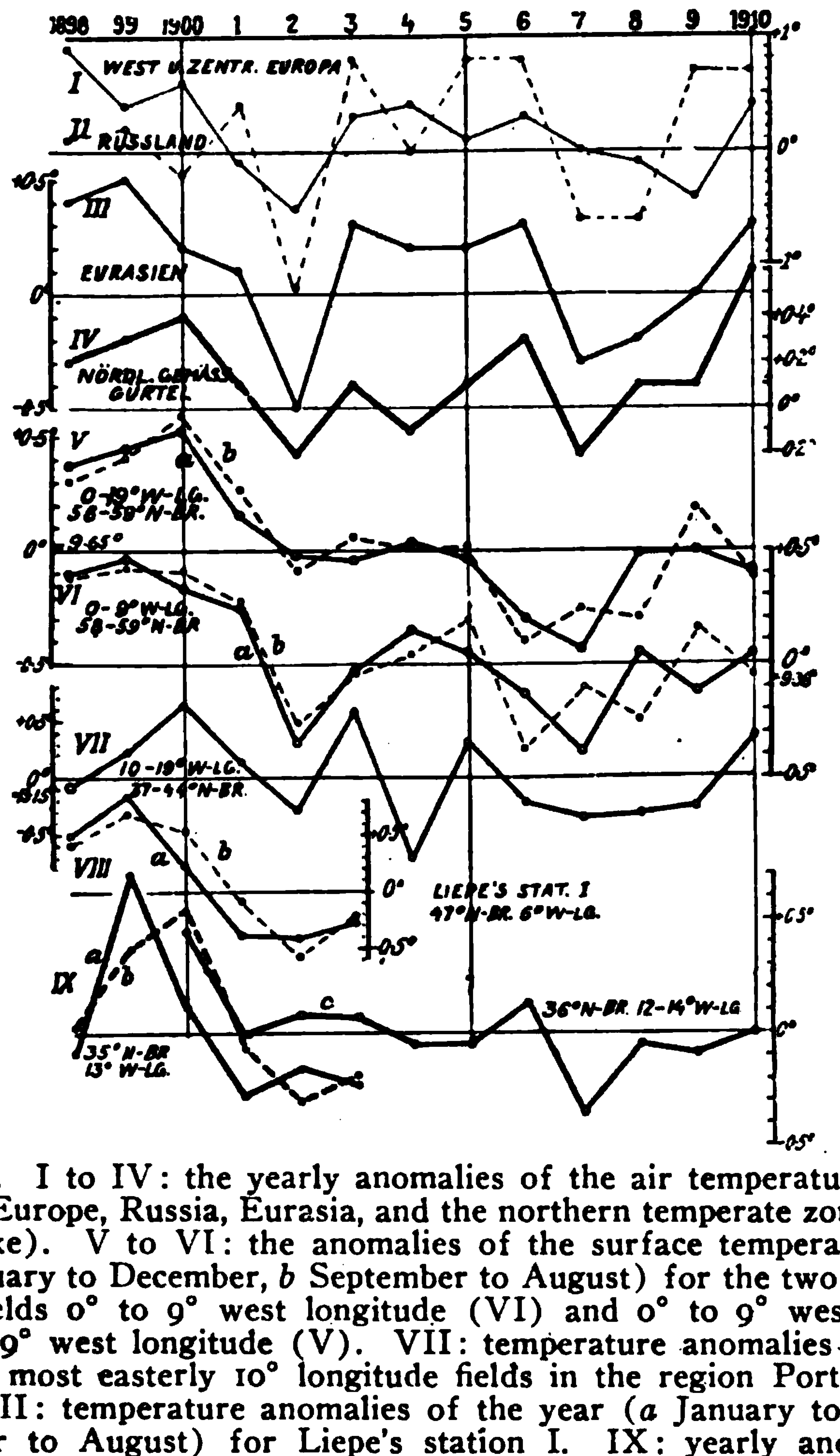

FIGURE 61. I to IV: the yearly anomalies of the air temperatures in west and central Europe, Russia, Eurasia, and the northern temperate zone (according to Mielke). V to VI: the anomalies of the surface temperature of the year (*a* January to December, *b* September to August) for the two Danish 10° longitude fields 0° to 9° west longitude (VI) and 0° to 9° west longitude and 10° to 19° west longitude (V). VII: temperature anomalies for February for our most easterly 10° longitude fields in the region Portugal to the Azores. VIII: temperature anomalies of the year (*a* January to December, *b* September to August) for Liepe's station I. IX: yearly anomalies for Liepe's station III (*a* January to December, *b* September to August) and for the most northerly field of the Central Bureau (*c*).

A corresponding similarity for two different types of curves we find also for a considerable period of years if we compare the temperature variations at Petersen's and Liepe's stations with the air temperature variations in the above mentioned regions of the earth. In figure 62 we give curves I and II for the temperature variations

of Petersen's middle stations III to VIII (between 22° and 47° west longitude; see also fig. 1, stations 3 to 8) and in Liepe's three most southerly stations (pl. 15, stations VI, VII, VIII) which correspond best with the relations of the middle part of the Atlantic Ocean. These curves we have continued on by means of the curves Ib and IIb for the most western Danish fields 30° to 39° west longitude, and the Dutch field 5° to 14° north latitude, 25° to 34° west

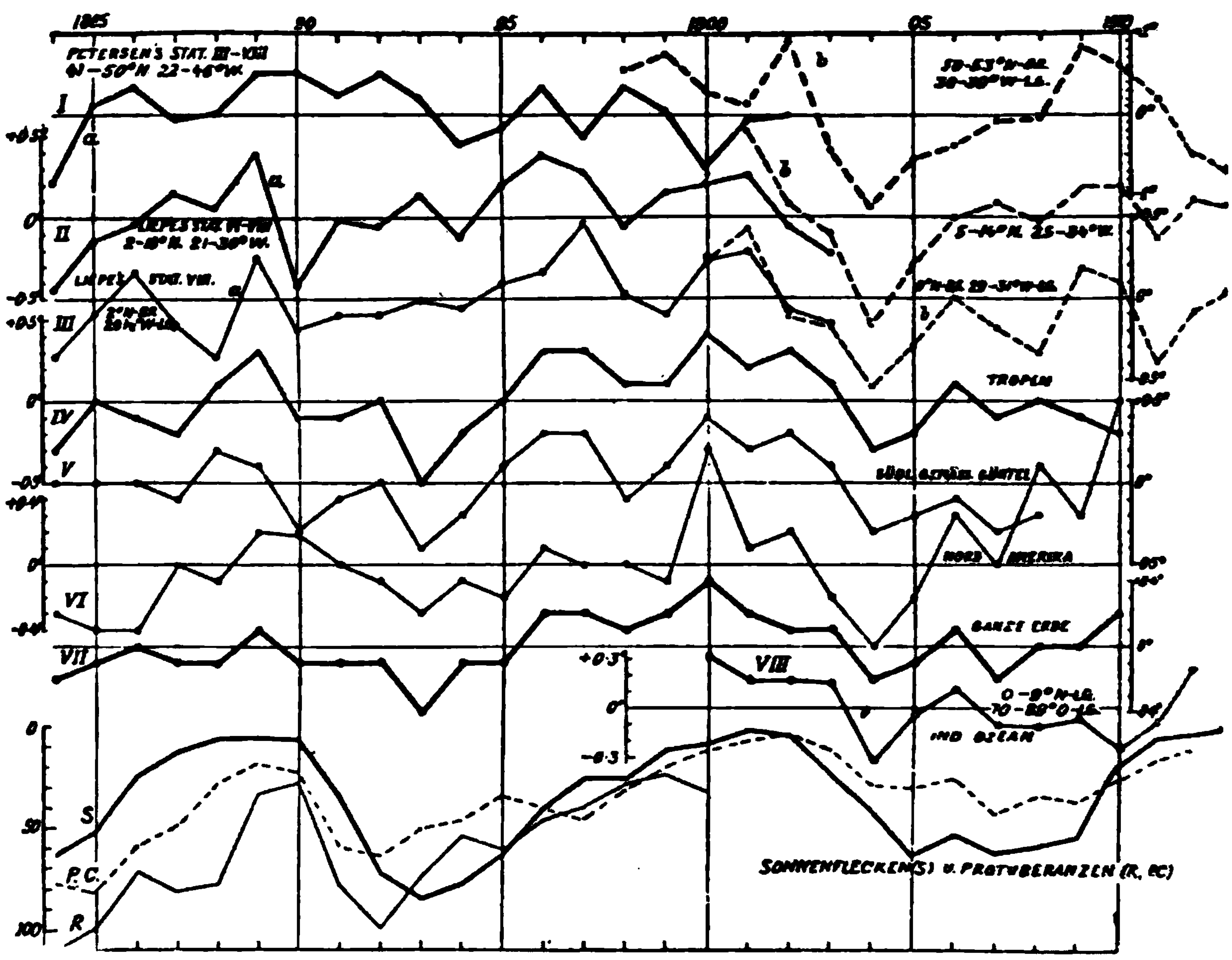

FIGURE 62. Yearly anomalies of the surface temperature (I to III, VIII) and the air temperature (I to VII). S: inverted curve of the smoothed relative sun spot numbers according to Wolfer. Scale on the left. P-C: daily number of prominences according to the observations in Palermo and Catania. Scale at the left where 100 equals 10.0. R: daily number of prominences observed at the Observatory of the Collegio Romano.

longitude. Curve IIIa for Liepe's station 8 near the equator we have continued on by means of curve IIIb for the equatorial field of the Atlantic, whose temperature was furnished us by the Central Bureau. These temperature curves for Petersen's and Liepe's stations and the three other fields show an unmistakable similarity to the temperature curves for the air in the tropics and in the other great regions which are mentioned above. Curve VIII for the surface temperature in the Indian Ocean shows also great similarity to the other curves.

In figure 63, curves I to III, we show the yearly variations in the surface temperature at Petersen's two most easterly stations I to II (at 12° and 18° west longitude) and at Liepe's three most northerly stations which are furthest east in the Atlantic along the coasts of England, France, and Portugal, (see fig. 1, stations I and II, pl. 15, stations I, II, and III). The curve for Liepe's station I is continued by means of the curve of the most northerly of the fields of the Central Bureau at 36° north (see curve IIIb). These curves show an unmistakable similarity to the curves IV to VI for the air temperature in Eurasia, in the north temperate zone and

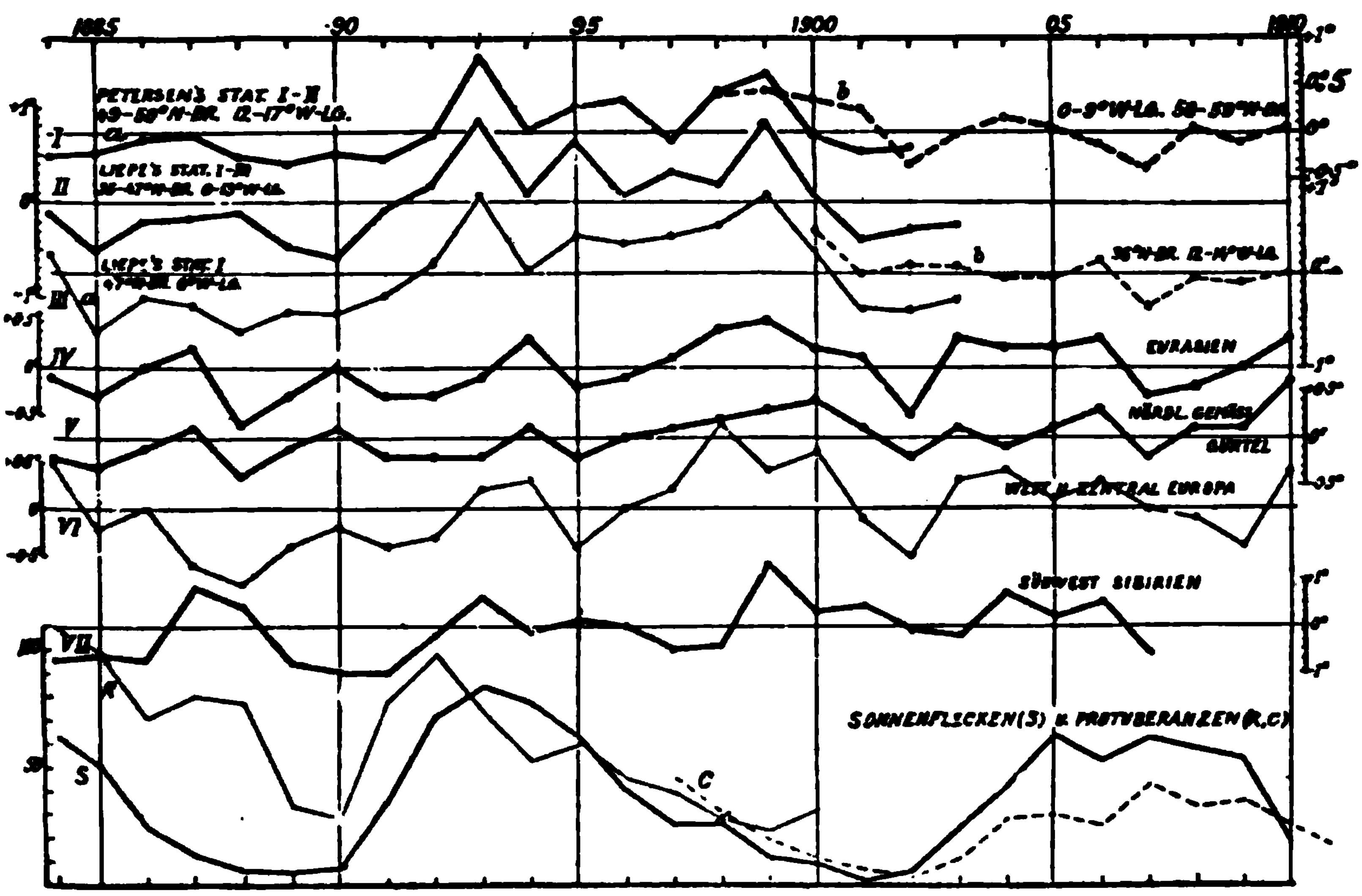

FIGURE 63. Yearly anomalies of the surface temperature (I to III) and the air temperature (IV to VII). S: direct sun spot curve, scale on the left. R: the number of prominences observed at the Observatory of the Collegio Romano. Scale at the left where 100 equals 10.0. C: daily number of prominences observed at Catania.

in west and middle Europe. We have also given a temperature curve VII for southwest Siberia and this shows a surprising agreement with the curves for Liepe's most northerly stations.

On figure 58 we give a three year smoothed curve (V) for the temperature in southwest Siberia. As may be seen, there is a good agreement between this curve and the curves I to IV, particularly the two curves I and III for Liepe's stations I to III and V to VI.

That so good agreement is found between the temperature variations in Siberia and the surface temperature in the fields of the ocean which experience the influence of the Azores pressure maximum is

not surprising in view of Hildebrandsson's theory, since Siberia has a well-marked pressure maximum in winter which is the most defining part of the year for the temperature. The two regions are therefore near two action centers of the same kind where the temperature variations should naturally agree. It is more surprising on the other hand, that the yearly curve for Siberia also shows similarity to the yearly curves for the most easterly Danish fields between 0° and 10° west longitude far north between 58° and 60° north latitude. (Compare fig. 63, curves VII and Ib). This lies completely under the influence of the Icelandic pressure minimum and according to Hildebrandsson should show an opposite march in the temperature variations. However, as we shall show later, there is a very natural explanation for this condition of affairs.

In figures 62 and 63 at the bottom are given curves for the sun spots (S) and for the protuberances (R, PC, and C). In figure 62 these curves are shown inverted, as indicated by the scale at the right. One sees that great similarity exists between these curves and the temperature curves of both figures, and even the small variations of the prominence curves, for example, in the years 1884 to 1901, are found in several curves for the surface temperature and for the air temperature, although part of the variations of figure 62 and 63 occur in opposite senses.

X. EARLIER INVESTIGATIONS ON THE RELATION BETWEEN VARIATIONS OF SOLAR ACTIVITY AND THE METEOROLOGICAL PHENOMENA ON THE EARTH

Recent investigations have made it more and more clear that a dependence exists between the variations of different phenomena on the earth and the variations of the activity of the sun. Among these variations are the number and extent of the sun spots, the faculae and the prominences. That an intimate connection exists between these and the magnetic forces and the Northern Lights has been known as the result of numerous observations, but it has gradually become more probable that there are short and long periods in the variations of meteorological elements on the earth and the corresponding periods in the activity of the sun. It is *a priori* probable that variations in the solar activity, either directly or indirectly, must call forth corresponding variations in the meteorological elements in the

TEMPERATURE VARIATIONS AND SUN SPOTS

Only a short time after the discovery of sun spots by the Englishman Harriot on December 10, 1610, the German Joh. Fabricius on March 9, 1611, the Italian Galileo, and the German Jesuit Scheiner, the Jesuit Father Riccioli in the year 1651 announced that with a decrease of the sun spots the temperature of the earth increases and with an increase of them it diminishes. Later on many investigators occupied themselves with this matter of whom some found the relation to be inverse, the temperature rising with increasing numbers of sun spots. Among the latter may be mentioned William Herschel (1801), who came to this conclusion through studies of the wheat prices in Windsor.

The Bavarian astronomer Gruithuisen came to the same conclusion in 1826, but he also made the following peculiar announcement which was based on thirty-six years' experience in Munich. " Settled fine weather occurs on the earth, when on the sun the variable weather (that is, sun spot formation) ceases. Great spots call forth on the earth variable weather differing greatly in different localities. The more scattered the spots occur, the less does the temperature of the earth's atmosphere rise since only spot groups or great spots send forth more heat." (See Mielke, 1913, p. 1).

Alfred Gautier (1844) of Geneva, like many others, arrived at the conclusion that years of many sun spots were colder than those with few. He also made the valuable discovery that a periodicity occurs in the spots and he determined the period as about ten years, that is, five years after each sun spot maximum there follows a minimum.[1] This period which had been observed since 1825 by Schwabe, was soon more accurately and thoroughly determined by Rudolf Wolf in Zurich, who found it to be eleven and one-ninth years.

We can mention here only a few of the investigations in this field, and must refer to the historic treatises on the subject, as for example those of von Hahn (1877), Fritz (1878-1893), S. Gunther (1899), Arrhenius (1903), Hann (1908), Wallén (1910), and Mielke (1913).

After the assembly of a great quantity of observational material, taken over the period of time from 1744 (or even 1719 at Berlin) to 1851 at Milan, Vienna, Kremsmunster, Hohenpeissenberg, Prague,

[1] Already in the year 1776 the Dane Horrebow in his day book of unpublished observations indicated the probability that one would find a period in the variations of the sun spots and that this might also be of importance to the planets which are carried on by the sun and lighted by it.

Berlin, St. Petersburg, Fritsch (1854) came to the conclusion that the temperature during increase of sun spots fell off yearly about 0.5° C. and vice versa, increased to that amount with decreasing sun spot activity. R. Wolf came to similar results in the year 1859 by the investigation of the temperature series at Berlin, and Zimmermann also from the Hamburg observations.

The most thorough investigations of recent times are those of W. Köppen published in the year 1873. He used observations at 403 stations which he divided into 25 regions distributed over the whole earth, and which he separated into five climatic zones. He reached the conclusion that the heat maximum in the tropics is from a half year to one and a half years (on the average nine-tenths year) before the corresponding sun spot minimum, and more retarded the further one goes from the equator. The temperature minimum in the tropics occurs about the time of sun spot maximum. The temperature variations show themselves most regularly and distinctly in the tropics with an average amplitude of 0.73° C., falling off in magnitude towards the poles. The temperature amplitude at the investigated stations outside the tropics had an average value of 0.54° C.

Köppen found besides that the agreement between temperature variations and sun spot variations is not always the same. While the temperature curve in the period from 1816 to 1859 followed closely the inverted sun spot curve, before and after this time, there was only a slight degree of correspondence. By later investigations in the year 1881 Köppen found that disagreements between the two curves lasted from 1859 to 1875.

Schuster (1885) came to the same conclusion as Köppen. R. Wolf advanced the view (Astr. Mitt. XXXIV) that in the year 1859 the sun spot curve quite radically changed its form, and together with it also the curve of the variation of the magnetic declination. Blanford (1891) found, however, that for the later times there is a good agreement between both curves as shown by the collection of numerous observations for India and he concluded therefrom that the earlier found disagreement after 1860 depended mainly on lack of exact observations.

Blanford published also (1891) a series of temperature measurements which were taken by Prof. Hill with the solar thermometer, that is, the black bulb and vacuum thermometer, for the years 1875 to 1885 in Allahabad. The measured mean value for the year varied oppositely as the sun spot numbers and was 3.7° C. (6.6° F.) higher at sun spot minimum than at maximum.

ıe same time that Köppen's treatise already referred to hed, spectroscopic investigations that were made, particu- ockyer, indicated that the sun is probably hotter at the n spot maximum. The results of Köppen and others that ıperature of the earth is colder at maximum than at mini- ıed therefore to be paradoxical. This was explained by (1875) by suggesting that the air temperature of the land ıch as those which Köppen investigated must be deter- by the quantity of heat that falls on the exterior of the by that which penetrates to the earth's surface, chiefly to urface of the globe. The greater part of the earth's sur- ;, however, one of water, the principal immediate effect of heat must be the increase of evaporation and therefore as ıent process the cloud and to rain fall. Now a cloudy :e intercepts the greater part of the solar heat, and the ation of the fallen rain lowers the temperature of the rom which it evaporates and that of the stratum of air : with it. The heat liberated by cloud condensation doubt- s the temperature of the air at the altitude of the cloudy but at the same time we have two causes at work equally ɔ depress that of the lowest stratum. Accordingly it must ed that an increase of the evaporation and of the rain by solar activity would cause a diminution of the tempera- the earth's surface.

Hill (1879) investigated the absolute yearly temperature in the mean of different stations in North India and found reatest variation occurred in the neighborhood of the mini- sun spots and the smallest variation in the neighborhood ın spot maximum. The agreement was not particularly reat departures occurred and the investigation embraced years 1866 and 1878. More trustworthy results he thought to obtain by investigating the mean yearly variation of the monthly mean of the temperature of different stations in North India for the years 1863 to 1878. He found that the greatest yearly variation occurred one or two years after the minimum of sun spots and the smallest variation in the year after the sun spot maximum. This relation, if such relation exists, seems more clearly to occur the further we go toward the northwest in India. He himself, however, notes that the observational material is very fragmentary. He appears to be of the opinion that since an increase of the amplitude of yearly heat variation probably is more associated with a greater

summer heat than with the greater winter cold, the relation which he found, if it exists, can only be explained by increased solar radiation at the time of sun spot minimum.

Dr. Hahn (1877) has shown that for Leipsic the difference of the absolute yearly extremes of the temperature varies directly as the sun spots. This is completely confirmed by Liznar (1880) by observations at eight other stations in Europe. In the years of sun spot maxima occur the highest temperature maxima and the lowest minima, while in years of sun spot minima the relation is inverted. (Compare Hann 1908, p. 358). Liznar also investigated the temperature variations at thirteen stations, among these St. Petersburg, Calcutta, and Hobart (Tasmania), and found for all some agreement with the eleven-year sun spot periods. For Vienna, Prague, Tuschaslau, Brünn, and Trieste, 1857 to 1870, he found that the mean of the daily amplitude was smallest in the years 1859 and 1860, and 1870-71, at sun spot maximum, while the greatest daily amplitude occurred about two years from the sun spot minimum. This was accordingly exactly opposite to what he found for the yearly range of temperature.

Unterweger (1891) believed that he found a short period of between 26 and 30 days in the sun spots and in the solar activity. This period while not produced by the rotation of the sun yet was influenced by it and occurred in the average in 29.56 (± 0.5) days. Further, he found a period of 69.4 days fairly strongly developed and besides this various others less distinct. In a review of Unterweger's investigations Köppen thinks (1891) that he has confirmed the existence of such short periods but he did not obtain the same values of their duration as those of Unterweger.

Frank H. Bigelow found (1894) a periodicity in the variations of the terrestrial forces as measured in Europe, in correlation with the rotation period of the sun. The period was computed t be 26.68 days, so that, for example, discernible minima in the ter restrial magnetic forces occurred on the first to second, fifth, nint fifteenth, twentieth, and twenty-fourth day of each rotation, whi on the other hand the maxima occurred on the third, seventh, eleven to fourteenth, sixteenth to nineteenth, twenty-second, and twen

This he interprets as follows: What he calls the "polar magnetic radiation" of the sun is unequal over the sun's surface and may be divided between meridians of greater and less density. This "magnetic radiation" would reach the earth with varying intensity according to the meridian of the sun which sends it. This should be concentrated in oval regions which surround our magnetic and geographical poles up to 60° magnetic polar distance. Comparing the terrestrial magnetic variations within each solar rotation with temperature variations in the United States in the same period of 28.68 days he finds good agreement. Nevertheless the variation of temperature is sometimes in the *same direction* as the variation of the magnetic force, at other times *inverted*. He gives graphically the observed temperature anomalies for each solar rotation and arranges these curves into two classes, according as they go generally in the same way or the opposite way to the average magnetic curves for these periods, and finds about equal numbers of each sort. The two mean curves of each of these groups of direct or inverted curves, and also the values which obtain when one takes the values of the inverted curves from the values of the direct ones, show a marked similarity with the curves of the average magnetic variations within the 26.68 day period. Particularly striking is this for the curves which Bigelow found in this way for five stations in Dakota for the time interval 1878 to 1893 which includes about 220 solar rotations. These three curves (for the direct, inverted, and direct minus inverted temperature variations) are almost completely congruent with the magnetic curve and it appears scarcely possible to deny that this indicates real dependence. This further indicates that the sun sends unequal quantities of energy, during its rotation period, and this short interval variation in the received quantity of energy produces corresponding short period variations in the condition of the atmosphere, at least in the United States. The air temperature varies in association therewith sometimes in the same *direction* as the energy variations and sometimes the *opposite*.

From Bigelow's investigations it appears that the inverted variations occur on the whole during half the number of the rotation periods of the sun in the course of many years, and that the distribution of these inverted periods varies accordingly to the sun spot period. At the time of sun spot maxima they fall generally in the summer months or in the autumn months, but at the time of sun spot minima generally in the winter months. Bigelow does not propose any general explanation for this relation, but according to

the lines on which we interpret the connection of temperature variations with variations of solar activity we think that there is a natural explanation and we shall later return to it.

Bigelow sums up the temperature anomalies without regard to sign for the 26.68 day period for each year for his series 1878 to 1893, and obtains values which he calls temperature amplitude and which give in a fashion the degree over which the temperature varies within this solar rotation period. The curve which exhibits the variations found in this way agrees excellently with the curve for the magnetic elements in Europe and partly with the curve for the sun spots. In this way he shows that increased magnetic activity within the solar rotation period is associated with increased temperature variations and the opposite.

The mean yearly temperature for thirty meteorological stations in the United States varies as Bigelow finds for the period 1878 to 1893 oppositely with the magnetic elements and oppositely also with the sun spots. This he thinks is in agreement with his theory on the anti-cyclonic and cyclonic circulations which according to him vary directly with what he terms the " solar magnetic radiation."

Later Bigelow continued his investigations on the dependence between the meteorological variations and the solar activity and was confirmed in his first conclusion that lowering of the temperature in the United States attends an increase of the " solar magnetic intensity " and vice versa. This holds not only for the longer periods of eleven years, but also for short periods of two and three-fourths years which he found in 1898 and of which there are four within the eleven-year period.

He extended his investigations to a great number of stations in different parts of the world for the time 1873 to 1900 and took into consideration also the variations in the solar prominences as given by Lockyer in his paper 1903. Bigelow finds in the temperature variations a more or less distinct period of about three years. But the variations within this period behaved differently in differparts of the earth. This the Lockyers also found for the air pressure. Bigelow distinguishes between three types of curves for the variations:

1. The direct type, where the temperature variations go the same way as the variations in the number of the prominences.

2. The indirect type, where the variations in the temperature go in opposite directions to those of the prominences.

3. The indifferent type, when the temperature variations have no satisfactory agreement with the variations of the prominences.

The direct type of temperature curves he found within the tropics, in South America, Australia, and South Africa, also in North Africa, southwest Europe (France and Spain), in the most westerly of the United States, on the coast of the Pacific Ocean, and in Honolulu and west Greenland.

The indirect type he found in Japan and China, northwest, middle and southeast Russia, in middle Europe, on the Faroe Islands, on Iceland, east Greenland, and the following parts of the United States: the South Atlantic States, west Gulf States, and the states of the Great Lakes.

The indifferent type he found in the highest parts of India, in middle Siberia, southwest Russia, and in the following regions of the United States: in the North Atlantic States, on the north and south plateau states of the Rocky Mountains.

It is apparent that these different temperature regions have considerable similarity with those which Hildebrandsson found, taking into account the different action centers.

In a later treatise (1908) Bigelow compares the variations in the solar prominences for the years 1872 to 1905 with the yearly variations in the magnetic horizontal intensity in Europe, the air temperature, the vapor pressure, and the air pressure in different regions of the United States. He finds an eleven-year period in the variations of all these elements and a shorter period of about three, or more accurately 2.75 years. In the eleven-year period, which is shown most strongly in the United States along the Pacific Ocean, as also in the tropics, and less strongly easterly of the Rocky Mountains, the temperature and vapor pressure vary both in the west and in the east oppositely as the prominences and the magnetic force. In the short period which he found everywhere prominent, it appears that in the western states on the coast of the Pacific Ocean the temperature and the vapor pressure varied in the same direction with the prominences and the magnetic force, while on the Rocky Mountain plateau and eastward to the Atlantic coast the variation was opposite to these. There is, however, some phase displacement in the easterly region.

Bigelow finds the simplest explanation of this inversion of temperature variations through the horizontal air circulation. A rise of temperature in the tropics accompanying increased solar radiation would produce a horizontal flow of cold air from high latitudes and tend to cool the temperate regions by the cold winds.

A high pressure zone extends westward from Florida towards northern California and Oregon which divides the United States into two parts, so that he thinks the Pacific States are associated with the tropical system and the influence on the temperature of the United States is not directly an action of solar radiation, but only indirectly called forth by the heat which is carried by horizontal air currents.

We have summarized so far the investigations of Bigelow, because they have many points of interest in connection with our results, even though we differ from him in some respects.

In his well-known work on Climatic Variations since 1700, Brückner (1900) treats of the secular variations of the temperature of the earth and compares them with the variations of air pressure and rain fall. He finds a well-marked period of variation of these elements of approximately thirty-six years. By a collection of observations on the ice condition of rivers, on the date of the wine harvest and on the frequency of strong winds for several hundred years, he determines this period exactly as 34.8 ± 0.7 years. The amplitude of the temperature variations within this period " is in all parts of the earth approximately of equal magnitude at about 1° C." This is considerably greater than the amplitude of the eleven-year period according to Köppen. Brückner finds that his secular climatic variation with the period of about thirty-five or thirty-six years, has absolutely no connection with the sun spot frequency."

He concludes " there can be no doubt that the variations of the temperature are the primary effects, variations of air pressure and rain fall on the other hand secondary." The cause of the observed terrestrial temperature variations according to his thought can be sought in the oscillation of the heat coming in from the sun. In years with stronger solar radiation, land in summer would be warm to a greater degree, which would tend to produce relatively lower air pressure over the land with respect to that over the ocean. In winter it is, however, the reverse: for the land would be strongly cooled by the outgoing radiation, while the ocean would retain an excess of heat which is piled up during the summer, so that the temperature difference between ocean and continent is again abnormally great, this time in favor of the ocean. Furthermore, the air pressure difference is also accentuated: the barometer stands too low on the ocean, too high on the land. This intensification of the winte[illegible] the land can in its turn influence the [illegible] [illegible]oing radiation.

Brückner actually found that in Siberia and south Russia in periods otherwise warm and dry, particularly 1856-65, the winter was abnormally cold, the summer abnormally hot. However he remarks that south Russia and Siberia are distinguished by a peculiar march of temperature. The variations there march partly reversed from other regions. He is of the opinion that these irregularities "find their explanation by the great cold of their winter."

Brückner raises the interesting point that the temperature amplitude of his thirty-five year period seems to be less in the tropics than in higher latitudes, while the amplitude of the eleven-year period of Köppen is affected in the opposite direction.

After Brückner, William Lockyer, in 1901, considering the magnetic epochs, and the variation in the length of the sun spot period itself, worked out the period of the frequency of sun spots to be about 35.4 years. The time between minimum and maximum varies regularly in a cycle of about 35 years. Bigelow (1902) found in different ways a period of about thirty-five years in the variations of the sun spots and the magnetic horizontal intensity (see also J. Rekstad, 1908, pl. 1). Schuster, in 1905, derived a period of sun spots of 33.375 years. Besides he finds also shorter periods of 13.57, 11.125, 8.38, 5.625, 4.81, 3.78 and 2.69 years.

F. G. Hahn (1877) undertook investigations on the separate year seasons of meteorological elements of the several yearly seasons separately and connected their variations with those of the solar spots. He found, as a general rule, that the temperature varies oppositely as the sun spots, although this was not equally marked in all times of the year.

By considering the daily maximum temperatures in summer in Geneva for five sun spot periods after 1843, MacDowall (1896) found that "in sun spot maximum years a greater number as well of very hot as of very cold days occurs than in sun spot minimum years." He would explain this by the consideration that the sun's radiation has greater intensity at sun spot maximum than at minimum. Thus a greater number of very hot days at maximum should be expected, but it may be the cause also of greater evaporation and cloud building which may call forth very cold days. MacDowall has also given curves for the June temperature in Trieste, Paris, Aix la Chappelle, and Bremen for the years 1831 to 1893, and these show much correspondence with the inverted sun spot curves, particularly after 1860, with amplitudes between maxima and minima from 1.5° to 2° C. His five-year smoothed August curves for

Bremen show well marked agreement with the inverted sun spot curve for the five sun spot periods 1830-83, but it appears that the temperature in the period after 1883 went partly in the opposite direction. His five-year smooth curve for the summer temperature (April to September) in Bremen, agrees also very well with the inverted sun spot curve for the four periods 1830 to 1870, but less well with the two following periods 1870 to 1893.

It has also been found that the time of the formation of the grapes, the time of the vintage, and also the blossoming time of different plants in middle Europe and west Europe varies with the number of sun spots (so also the return of swallows in France). These phenological phenomena point to the fact that in these regions the spring months in the years rich in sun spots are warmer than those of less sun spots. This has been confirmed also by Flammarion for middle France and by Arrhenius (1903, p. 145) for north Sweden.

By a collection of the summer temperatures in Turin from about 1752 on, and their comparison with sun spots, Rizzo found (1897) that a temperature minimum follows about three years after a sun spot minimum, and a temperature maximum about three years after the sun spot maximum, with a temperature amplitude of 0.43° C.

C. Nordmann (1903) investigated the yearly temperatures for the interval 1870 to 1900 for thirteen tropical stations divided into zones around the earth. He found that in the eleven-year period the temperature very distinctly varied oppositely as the number of sun spots, as found earlier by Köppen. But his amplitude between maxima and minima was somewhat less and averaged 0.57° C.

By a special form of analysis, Alfred Angot (1903) examined the variations in altogether seventeen temperature periods, each corresponding with an eleven-year sun spot period and six tropical stations. In fifteen of the periods he found that the temperature varied oppositely with the sun spot numbers, while for two series 1857 to 1867 for Bombay and 1875- 86 for Barbadoes, the variation was in the same direction as that of the spots.

Easton (1905) maintained that in the last three hundred years the approach of cold winter gave the best indication of effect of great variations in the solar activity on the climate of the whole earth. In the temperature zones the sun spot frequency was particularly well reflected by the approach of very cold winter (see Hann, 1908, p. 358).

From about a hundred years' observations in Vienna, Hann found (1908, p. 357) that the temperature both in winter and summer is

highest at sun spot minimum and lowest at sun spot maximum, and the amplitude between the two he determined on the average for winter to be 0.61° C., for summer 0.48° C., while for the year it is only 0.25° C.

Newcomb (1908) investigated by means of a special mathematical process temperature series for the years 1871 to 1904 in widely separated regions covering the tropics and the lower latitudes of the United States, Argentina, West Indies, Mauretius, India, Ceylon, Australia, and the Pacific Ocean. He found the temperature maximum occurs 0.33 years before the sun spot minimum and the temperature minimum 0.65 years after the sun spot maximum. The amplitude between temperature maximum and minimum he determined as 0.26° C. The result is similar to that of Köppen only that Newcomb's amplitude is considerably smaller.

Newcomb concluded from this that the observed difference in the temperature of the earth indicated a corresponding fluctuation in the radiation of the sun of 0.2 per cent on both sides of the mean. He found further a somewhat doubtful indication of another variation in the temperature of the earth with a period of about six years, which could most probably be associated with variations of the radiation of the sun. This was first noticeable after the year 1870 and the average deviation from the mean temperature was less than 0.1° C. Finally he found, though without decisive proof, that "there is a certain suspicion of a tendency in the terrestrial temperature to fluctuate in a period corresponding to that of the sun's synodic rotation. If the fluctuations are real they affect our temperatures only by a small fraction of one-tenth of a degree." This agrees to a certain measure with Bigelow's result (1894), except that Newcomb's variations are much smaller. But he treated his observational material in a wholly different way and, for example, took no account of the consideration which Bigelow advances that by the variations in the solar radiation (which Bigelow calls the "polar magnetic solar radiation") variations could be produced in the temperature of the United States at certain times in the same direction, at other times in the reverse.

By means of bolometric measurements made in Washington, Langley (1904) found it probable that the solar radiation outside our atmosphere ("the solar constant") from the end of March, 1903, and for the rest of that year was about ten per cent diminished. By collection of temperature observations at 89 stations in seven different regions of the North Temperate Zone in Asia, Europe, North

Africa, and in North America, he found that in all of these seven regions the temperature nearly simultaneously sank. The temperature decrease in Germany amounted to more than 2° C. Nevertheless he found a rise in the temperature toward the end of the year that did not correspond with variations in the observed value of the solar constant. This he explained by increased tranparency in the atmosphere which had been noticed in September of this year.

Though Langley stated these results with great reserve and caution, they seem to indicate that the temperature on the surface of the earth varies directly with the solar radiation, a conclusion which, however, was strongly shaken by later investigations.

Abbot and Fowle (1908) collected the anomalies of monthly temperature for forty-seven stations in different parts of the earth. Since they assumed that the temperature of the earth would vary directly with the variations in the received solar radiation, they chose stations which were inland as far as possible, where the direct solar radiation would make itself most felt without experiencing much the equalizing influence of the ocean.

Their forty-seven stations were ranged in eight regions: North America (15), South America (1), middle and east Europe (8), North Africa (2), South Africa (2), North Asia (7), South Asia (6), Australia (6). The curves for each of these regions appear to be very irregular, but the mean for each year for all regions and all temperatures shows an eleven-year period that varies oppositely to the sun spots. Their curve (1908, pl. XXV-A) shows also well-marked three or four divisions of the eleven-year period, particularly in the last period, 1889 to 1900. Though they do not call attention to this, it seems very similar to the periods of sun spots, prominences, and magnetic elements as shown in our figure 95. In this publication these authors are inclined to the view that temperature variations follow directly variations of the solar radiation received, and consequently that this will be less at sun spot maximum, which, however, is a view they later found to be erroneous (1913-a).

In a later work (1913-b) Abbot and Fowle investigated the dependence between volcanic eruptions and variations in the air temperature of the earth. They came thereby to the conclusion that the solar radiation which reaches us is diminished by the masses of volcanic dust, which are thrown out by powerful explosive volcanic eruptions and distributed at great heights in the atmosphere. Such eruptions are those of Krakatao in August 1883, Mt. Pelee (Mar-

tinique) in May, 1902, Santa Maria (Guatemala) in October 1902, Colima (Southern Mexico) February and March 1903, Katmai (Alaska) in June, 1912, and many others. The small dust particles reflect and scatter the solar radiation. A diminution of the heat available to warm the earth makes itself distinctly felt in the pyrheliometric curve, as measurements they cite tend to show. The pyrheliometric curve has well-marked minima in the years 1884-5, 1890-91, and 1903, corresponding with great volcanic eruptions. By combining in a certain way the mean of this curve and the inverted sun spot curve together, they produce a curve from the year 1880 to 1909, which has very great similarity with the curve for the anomalies of the maximum temperatures of the United States at fifteen stations and also with the curve for the yearly temperature of the earth at forty-seven stations.

Arctowski has studied the climatic and temperature variations in different regions of the earth in numerous papers (1908-1915). He comes to the conclusion that rythmical variations keep step with the variations in the solar activity, which show a well-marked eleven-year period, but the variations do not run parallel all over the earth. At most places they go oppositely to the sun spots, so that the average temperature of the earth is considerably lower (at least 0.5° C.) at sun spot maximum than at minimum. In some scattered regions the temperature variations go in the same direction as the sun spots, but not always regularly. He finds (1909, p. 124) that in a year of maximum sun spots like 1893, the pleions as he calls them (that is to say, the regions of positive temperature anomalies) are isolated on a ground of negative anomalies, while during years of sun spot minima like 1900 conversely the antipleions (that is, regions of negative temperature anomalies) are the isolated spots.

The most sharply marked period in most of Arctowski's temperature curves, particularly of tropical stations, is not the eleven-year period, but a shorter somewhat irregular one whose average length is 2.75 years, and which is the same as that found by Bigelow and the two Lockyers. Indeed this shorter period variation he finds so predominently that he recently (1915, p. 171) has spoken of it as certain that the variations in Arequipa (Peru) or in the equatorial type of temperature curves apparently have nothing in common with the eleven-year period, though a certain correlation can exist. He is of the opinion that the shorter variations are brought forth by corresponding shorter variations in the solar activity. Volcanic dust, Arctowski believes himself to have shown (1915) has

no particular influence to produce great variations in the temperature of the earth except in quite exceptional cases like the Krakatao outbreak.

In the tropics, he believes, the temperature variations are developed most regularly, merely under the influence of variations in the solar activity without the disturbing influence of atmospheric circulation. Indeed, by a comparison of temperature curves for Arequipa, Peru, with the curve of the observed value for the "solar constant" according to measures in Washington, 1903 to 1907, he believes that he has shown a correlation between variations in the monthly mean temperature and the observed short period variations of the "solar constant" (1912, p. 603).

By comparing the monthly mean of the fluctuating values of the "solar constant" found on Mt. Wilson in the years 1905 and 1906 with the monthly mean temperatures for Arequipa for the same months, Arctowski found it probable that an anomaly of 1° F. of the monthly temperature for Arequipa corresponds to an anomaly of about 0.015 calorie for the "solar constant." The extreme values of the "solar constant," which were found on Mt. Wilson in these measurements were 1.93 and 2.14 calories per square centimeter per minute outside the earth's atmosphere.[1]

Plainly misled by Abbot and Fowle, who in their work in the year 1907 showed it probable that the temperature variations of the earth march directly with variations in the solar radiation, Arctowski came to the conclusion that the temperature of the earth, particularly in the tropics, varies directly as the solar radiation. In their later work (1913–a) Abbot and Fowle have, however, shown that they were probably in error in this view and that the "solar constant" is smaller at sun spot minimum than at sun spot maximum, therefore Arctowski's view would be untenable. In his latest paper (1915) he appears like Huntington to attribute a greater influence to the atmospheric circulation. Particularly interesting are Arctowski's studies of his pleions and antipleions (1909, 1910, and 1914), which he finds may be perpetuated over several years with the centers of the pleions traveling from year to year to and fro in irregular curves.

We have shown (1909, p. 214) that the winter temperature from 1st of November to 30th of April in Norway, at Ona Lighthouse for the years 1874 to 1907 changes in the same way as the sun spots so

[1] In a late publication of Abbot, Fowle, and Aldrich (1913-a) these numerical values are diminished by 5 per cent owing to improvements in pyrheliometry.

that high winter temperatures fall coincidently with sun spot maximum.

In his valuable work on the height of the water in the great Swedish lakes, Dr. Axel Wallen (1910 to 1913) has also studied the variations of the air temperature at Stockholm since the middle of the eighteenth century. He finds several short periods of one, two, and four weeks,[1] and longer periods of twelve, and twenty-five or twenty-six months, and then of eleven years and thirty-three years, and an extremely long period of more than one hundred and ten years. The eleven-year period is double, with two maxima and two minima. The two minima are about equally intense, the principal maximum considerably stronger than the second maximum. This distribution is, however, very irregular, comes out only in the means of a long series of years, and is most clearly indicated by the winter temperature. It is not improbable that the period of thirty-three years is divisible in a similar manner.

The periods of a few years and of eleven years in temperature variations were also found by Wallen in a series of stations in North Europe as well as in Upsala and Stockholm. The maxima and minima correspond completely at the different stations and appear to coincide at times. Furthermore he found that the winter temperatures are more strongly influenced than those of other seasons of the year in these variations.

Dr. Oscar V. Johansson employing smoothed five year means found that the temperature, the time of harvest, and the breaking up of ice in rivers in Finland apparently are somewhat more favorable at and somewhat after sun spot maximum than at sun spot minimum. Later (1912) by three year means of air temperature at Helsingfors he investigated whether the sun spot period is there doubled as found by Wallen (1910) for Sweden. Johansson's investigations showed rather plainly a double period. The two minima fall approximately with the sun spot extreme, and the two maxima fall approximately three or four years later. The two periods are about of equal intensity, only generally the curves at and after sun spot minimum are somewhat lower than those at and after the sun spot maximum. The complete amplitude is in summer only half that which it is in winter and for the year 1.4° C., about the

[1] Wallen thinks that these short periods depend upon the motion of the moon in a similar way that Otto Pettersson attributed to the moon certain oceanographic phenomena. He does not appear to have considered that his short periods may be associated with the synodic rotation of the sun.

same as found by Wallen for Karlstad-Vänersborg. Variations of temperature in Helsingfors were found in winter with periods of 3.0 years and in summer with 2.7 and for the year 2.9 years. According to Johansson it is very clear " that this short period variation, particularly for the winter, depends on the water temperature of the northern ocean (see also the results of Pettersson and Meinardus)." This conclusion must be understood in this way, that the air temperature in Helsingfors and the water temperature at the Norwegian lighthouses (not in the North Sea) show the same variation, so that the variations in temperature not only for Norway and Sweden, but also for Finland or parts of it are found in common.

In his paper on volcanic dust and climatic variations, Humphreys (1913) discusses yearly mean temperatures for the period 1872 to 1912, for seventeen stations in the United States, seven stations in Europe and one station in India. He has chosen stations which have considerable height above the sea. Most of them lie between 2,000 and 10,000 ft. elevation. The variations in these mean temperatures he has, like Abbot and Fowle (1913), compared with the variations in the number of sun spots, the variations in the measured solar radiation at the earth's surface as observed by the pyrheliometer, and also with the volcanic eruptions on the earth. He finds excellent agreement, and when he continues the combined curve for sun spots and pyrheliometric values at the earth's surface of Abbot and Fowle to the year 1913, he obtains a yet more convincing impression of agreement between this curve and the curve for the terrestrial temperature. He traces the curve of terrestrial temperature backwards to 1750 and compares it with the inverted sun spot curve and also with the recorded volcanic eruptions. While the two curves for temperature and sun spots show many dissimilarities, there appears to be a close correspondence between the years of low temperatures such as 1767, 1785, 1813 to 1816 and others, and the recorded violent volcanic eruptions. Humphreys comes therefore to the same conclusion as Abbot and Fowle, namely, that the variations in the temperature at the earth's surface are partially dependent on variations of solar activity which have the eleven-year or sun spot period and partly on the volcanic dust in the atmosphere of the earth. In consequence of the small diameter of the particles of the volcanic dust, it would have the tendency to diffusely reflect rays of short wave length like visible solar rays in a high degree, but rays of great wave length, such as those emitted by the earth's surface, would be freely transmitted. Hence the incoming

radiation toward the earth's surface would be 30 times as much diminished as the outgoing radiation from the earth. In Humphrey's opinion the eleven-year variations may be produced because the sunlight according to his view has less violet and ultra-violet rays at sun spot maximum than at minimum, on account of the presence in the solar corona at maximum of the maximum number of particles which reflect and scatter the light. Since the ultra-violet rays form ozone, conditions will be more favorable to its formation in the isothermal layer of our atmosphere above 11 kilometers altitude during sun spot minimum. But since the ozone has the peculiarity of transmitting the visible heat rays relatively freely but of hindering the escape of the long wave length rays emitted by the earth, the increased formation of ozone will be accompanied by a rise of temperature at the earth's surface because the outgoing radiation of the earth is diminished. We shall later return to the consideration of Humphrey's theories.

A valuable article was published by Dr. Johannes Mielke (1913) in which he discussed the yearly temperatures from 1869 to 1910, for not less than 487 different stations distributed over the whole earth. He has divided these stations into 25 regions, the same which Köppen had used before, and thereby has found means to determine the most probable expressions for the temperature of the different parts of the earth's surface during the investigated period. These temperature series show on the whole an unmistakable agreement with the variations in the number of sun spots, but this agreement is most marked for the tropics. As the average amplitude between the warmest years at sun spot minimum and the coldest years, at sun spot maximum, he finds for the tropics in the years 1820 to 1854: 0.65° C.; in the years 1870 to 1910: 0.40° C. Outside the tropics in the years 1820 to 1854: 0.51° C.; and the years 1870 to 1910: 0.35° C.

In the following year (1914) Köppen published a new investigation on the temperature of the earth, the sun spots, and the volcanic eruptions which was based principally on the two above mentioned articles of Mielke and Humphreys. He employed the values for the temperature series used by Mielke in order to construct curves which bring out clearly the agreement between the variations of the temperature of the earth's atmosphere and the sun spots (see fig. 65 below). The best agreement is found as already stated in the tropical variations. Köppen discussed Humphrey's theory that the temperature variations depend in part upon the volcanic erup-

tions in the earth's atmosphere. We shall later return to Köppen's paper.

As we were on the point of finishing this work, Krogness published (1917) in the Journal "Naturen" March, 1917, an interesting article on the dependence between magnetic storms and meteorological variations. The article is in part the result of highly valuable observations which Krogness made at the Haldde Observatory in Finmark. He urges that the variations in the earth's magnetism are at least as good a measure of the variations of the solar activity as the relative sun spot numbers which have been used principally hitherto. By employing the observations of the Christiania Observatory on the daily variations of the magnetic declination as a measure of the magnetic storminess, he finds that the eleven-year variations in this correspond directly to an eleven-year variation in the surface temperature at Ona Lighthouse on the Norwegian west coast. The correlation occurs in this way: that a maximum of temperature occurs at the time of maximum magnetic storminess and therefore at the time of sun spot maximum (compare Helland-Hansen and Nansen, 1909, fig. 73). He has investigated the relation between the variations in the magnetic storminess and the air temperature at different stations in Norway at different seasons of the year, both in the north (Alten and Andenes) and further south (Christiansund and Domaas). He finds that in March-April there is a good agreement in the variations of the magnetic storminess and the temperature variations not only in the stations which he investigated but also on the whole in all Norway (22 meteorological stations), so that the maximum magnetic storminess occurs a little before the maximum of air temperature. But different relations hold for other seasons of the year. In January, for example, the temperature variations at the stations he employed as well as in all Norway go in opposite direction to the variations of the magnetic storminess. Indications of the same kind are found in the autumn in the months September and October particularly in northern Norway. Considering the whole year as a unit, there appears to be a certain indication of agreement between temperature variations and variations in the magnetic storminess, but such that the maximum of temperature falls on the average a couple of years after the maximum of magnetic storminess. Krogness appears to think that the variations in the solar radiation which reaches the earth has a *direct* influence on the air temperature of the earth's surface at the different stations, and that this in combination with variations in the air circulation and outgoing radiation is the cause of the observed agreement which he finds between temperature

variations and the variations of magnetic storminess. Krogness goes on the assumption that the temperature of the sea at sun spot maximum is highest in consequence of the greater intensity of solar radiation, an assumption which for the open sea does not agree in general with our results.

In a later part of his article (" Naturen " for April, 1917) Krogness shows on the basis of the observations Heldde (1912-1915) a period of approximately 27.3 days and one of half that length, 14 days, in the magnetic storminess which associates itself with the synodic rotation of the sun. He finds also two very interesting periods of about eight months and of two years in the magnetic storminess in Christiania since 1843. These fall in with the period of about 236 days of the heliocentric conjunction of the planets Venus and Jupiter in combination with the yearly period of variation in declination in Christiania.[1] He publishes two curves: For the air temperature in all Norway and for the surface temperature at Ona Lighthouse. These two curves show this period of two years, but somewhat irregularly, so that it occasionally has a length of nearly three years, as in the interval 1883 to 1889, and occasionally is shorter than two years. The temperature curves vary in a majority of cases directly, but part of the time oppositely with the curve of magnetic storminess in Christiania. The eight monthly period is difficult to perceive in these curves.[2]

[1] Two periods of eight and twelve months are commensurate with one of twenty-four months and the intensified action can thus be caused which has a two years' period.

[2] In " Ann. der Hydr." for May, 1917, there appears a treatise " On the Relation of Temperature to Sun Spot Periods " by Otto Meissner. It is recalled there that the same author had already (Astr. Nachrichten Bd. 189, p. 371-374) shown that for Berlin the sun spot maximum corresponds with a temperature minimum and a precipitation maximum, while three years after the opposite extremes of phase succeed, and in the minimum between normal conditions prevail. Meissner investigates in the present article the temperature variations in Berlin for each month of the year during seven and one-half sun spot cycles from 1822 to 1907, and finds the following relation with the sun spot periods. In the three winter months and the three summer months there is a simple or double periodicity, most strongly marked in January and July though with greatly displaced phases. In spring and autumn such periodicity is not to be recognized. In January and February there is a principal minimum the year after the sun spot maximum while, for example, in July there is a minimum three years after the sun spot maximum and in the same year as the temperature maximum in January. July shows a principal minimum at the time of sun spot minimum, etc. The yearly mean shows a clearly double periodicity with a principal minimum at the time of sun spot maximum or a year later and a secondary minimum at the time of sun spot minimum.

VARIATIONS IN AIR PRESSURE AND IN SOLAR ACTIVITY

Variations of other meteorological elements have been connected with the variations of sun spots by various authors with greater or less evidences of agreement.

That the variations in air pressure are associated with unknown variations in the solar activity has long ago been suggested. Charles Chambers (1857) called attention to variations in the yearly barometric pressure in Bombay which show a periodicity which corresponds approximately with the sun spot period. A few years afterwards Frederick Chambers (1878) showed that the observed air pressure in Bombay for the winter and the summer months and for both together give lower values when the sun spots are more intensely developed and vice versa. But the curve for the air pressure lags somewhat behind the curve of sun spots, particularly in the years of the maximum of sun spots. The air pressure curve for the winter was more regular than the air pressure curve for the summer. From these observations Chambers drew the partly erroneous conclusion that since the variations of air pressure depend upon the warming of the earth's surface, the sun must be warmest and consequently the temperature of the earth must be highest at the maximum of sun spots, when a minimum of air pressure prevails.

In the same year, 1878, John Allen Broun supported Chambers' work by comparing the observations at Singapore, Trevandrum, Madras and Bombay and showed that the years with the highest and lowest mean air pressure were probably in common for all India. From this he drew the conclusion that in this whole region the air pressure *varies oppositely with the sun spots* in the same way that it does for Bombay. At the end of the same year, 1878, S. A. Hill confirmed this conclusion by similar data from Calcutta.

Hill investigated also (1879) the yearly amplitude for the variations of the air pressure in Calcutta from 1840 to 1878, as well as in Roorkee, from 1864 to 1878, and found that, like the yearly amplitude of temperature in northwestern India they changed oppositely with the sun spots, so that the maximum pressure amplitude was approximately exactly coincident with the sun spot minimum and vice versa. He was inclined to conclude from this that the "Solar radiation" is in general more intense at the minimum of sun spot."

In May, 1879, E. D. Archibald called attention to the remarkable condition which had been brought to his notice by S. A. Hill that in St. Petersburg the mean yearly air pressure varies in the same direction as the sun spots. It is highest at sun spot maximum and lowest

at minimum, but the period of air pressure variation lags behind the sun spot period.

Blanford (1879, 1880) extended his investigations over a larger region including observations at Batavia, Singapore, Colombo and several Indian stations and also Mauritius. He showed that in the whole Indo-Malayan region the air pressure varies oppositely with the sun spots. These variations were most clearly and regularly developed at island stations near the equator. But at the same time he obtained the highly interesting relation that as Hill and Archibald had found for St. Petersburg, namely, the air pressure there varied directly with the sun spots, also that for stations further east in Russia and Siberia as Ekaterinburg and Barnaul the same condition prevailed. This was also found less marked for the stations Bogoloves and Slatoust in the Urals. Furthermore he showed that these variations going directly with the sun spots prevailed only for the air pressure in winter in St. Petersburg, Ekaterinburg, and Barnaul, while his curves for the summer had a tendency to go in the opposite direction to the winter curves. He did not notice that the amplitude of his winter curves decreased in magnitude from St. Petersburg eastwards, nor did he note the extremely interesting thing that his summer curves for Ekaterinburg and Barnaul in general have the same character as both the summer curves and the yearly curves of the air pressure at the Indian stations. The air pressure in summer in the Siberian stations varies almost oppositely with the sun spots.

From this we see that between Russia and Siberia on the one hand and the Indo-Malayan region, perhaps also including the Chinese region, on the other hand, there is in winter an opposite and periodic oscillation of the air pressure in such a manner that while in winter in west Siberia and Russia maximum pressures prevail at sun spot maximum, minimum prevails in the Indo-Malayan region and vice versa at sun spot minimum. As he expresses it in a later publication (1891, p. 586) " in years of maximum sun spots a larger portion of the tropical atmosphere is transferred to high latitudes in the winter hemisphere, which again implies a disturbance of atmospheric equilibrium in that epoch between the tropics and the circumpolar zone and therefore an increased intensity of the disturbing agent." In the tropical stations he found a slight difference between the variations in air pressure in summer and winter. It behaved in both seasons of the year oppositely to the sun spots.

Blanford was of the opinion that the observed variations in air pressure must have their seat in the higher regions of the atmos-

phere, probably in the cloud-building layers. He draws this conclusion because the air pressure anomalies for the time of high pressure between May, 1876, and August, 1878, was considerably greater in the Himalayas at 6,900 feet than in the interior plains of Bengal. He furthermore draws the same conclusion from the fact brought out by Gautier and Köppen that the temperature of the atmosphere at the earth's surface varies in such a manner that it stands in opposite relation to the air pressure variation. On the one hand high temperature with high air pressure prevails at sun spot minimum, while at sun spot maximum low temperature and low air pressures prevail. He conceived it probable that the most important factor producing the observed diminution of air pressure at sun spot maximum is the increase of evaporation and the uprising of water vapor, which may produce effects of three kinds: First, that the water vapor displaces air whose density is three-eighths times greater; second, because the heat of condensation is set free in the higher layers; and third, because of the upward rising currents which may diminish the pressure of the atmosphere in a purely dynamical way. The first and second of these processes would not directly diminish the air pressure, but only the density of the air layer and thereby only increase its volume, but in this way a part of the upper atmosphere must be displaced and it would necessarily flow over into regions where the water vapor production is at a minimum and therefore into the polar regions and the colder parts of the temperature zone. This would occur particularly where a cold and dry continental surface tends to produce a strong outgoing radiation under a winter sky. These conditions are found exactly in the northern plains in European Russia and in west Siberia.

In the same year, 1880, Frederick Chambers investigated with the aid of all available data the variations of the air pressure for the period of years 1843 to 1879 in the tropical stations St. Helena, Mauritius, Bombay, Madras, Calcutta, Batavia, and Zikawai, and found an excellent agreement in the curves compared as regards the march of the air pressure in these different stations. This was of such a nature that variations in the westerly stations occurred several months earlier than in the stations further east. Chambers therefore assumed the existence of large atmospheric waves which slowly and with varying velocity traversed the earth from west to east like the cyclones in the ektropic regions.

He compared these air pressure curves for the different stations with the inverted sun spot curve and showed an excellent agree-

ment, but the times of maximum and minimum came after the corresponding times of minimum and maximum of sun spots. The time interval varies from about six months to about two and a half years. In the mean it was about one year eight months. He therefore concluded that several months after variations in the spotted surface of the sun there follow corresponding abnormal air pressure variations. He connected also the famines of India with these air pressure variations by showing that times of famine follow his atmospheric waves of high pressure.

By his above mentioned spectroscopic investigations of sun spots beginning with 1870, Sir Norman Lockyer in the year 1886 regarded it fairly certain that the sun is warmest at sun spot maximum. At sun spot minimum the widened lines in the sun spot spectrum corresponded generally with the lines of iron and some other known metals, but at maximum the most widened lines were the so-called unknowns, which had not been observed in the spectrum of terrestrial elements. He therefore provisionally assumed that the sun was not only warmer at sun spot maximum, but warm enough to dissociate the iron vapor.

In the year 1900, Sir Norman Lockyer and William Lockyer published a discussion of the observations of the most widened spectroscopic lines for a period of more than twenty years. They showed that the two kinds of spectroscopic lines experienced regular and opposite periodic variations at least up to the year 1894 or 1895. These variations were such that when expressed graphically in curves the curve for the iron lines tended upwards when the curve for the unknown lines tended downwards, and vice versa. This relation continued unchanged up to the year 1895. At certain intervals the two curves must therefore cross one another and this should occur according to the above mentioned hypothesis at the time when the temperature of the sun had a mean value. These crossing points lay as they found almost exactly in the mean between maximum and minimum of sun spots, that is to say, midway between those times when one should assume that the sun was warmer or colder than the mean.

In discussion of the variations of the solar prominences (1902) they found that the prominences on the whole varied in the same way as the sun spots, but that within the eleven-year sun spot period there occur three well marked shorter periods of about three and a half or 3.7 years in the variations of the prominences. These three periods occur so that while the maximum of the middle period

coincides with the maximum of sun spots, the maxima for the two other periods occur at the crossing points of the two kinds of spectrum lines.

In a discussion of this prominence curve along with the curves of air pressure variations in India they found an excellent agreement at least for the period of time 1877 to 1890, in so far that the air pressure curves showed the same periods of about 3.7 years. This was so distinctly marked that it rather overshadowed the eleven-year period, associated with the sun spot curves.

In order to see if this remarkable agreement was confined to the region of India they extended their investigations to other parts of the earth and investigated the air pressure variations in Cordoba, Argentina. They found also here a remarkable agreement, but with the important difference that the curves were inverted. Years with high air pressure in India corresponded with years of low air pressure in Cordoba. This held particularly for the time April to September, that is, the summer of the northern hemisphere and the winter of the southern hemisphere, and also for the whole year. On the other hand it was less closely followed for the summer of the southern hemisphere, that is, from October to March. It appears natural that these coincident variations should be due to a common cause which, while it tended to raise the mean barometric pressure of the low pressure months in the Indian region, tended at the same time to depress the mean value for the high pressure months at Cordoba. Further investigations show also that a similar coincidence of time in the air pressure variations at different stations in Europe occurs with a similar period of a few years.

The common cause for these air pressure variations must probably be outside of the earth, and it is easy to conclude that it may be associated with the coincident outbreak of prominences which also is associated with variations in the latitude of the sun spots on the sun's surface. All of these phenomena occur in the same period of about three and one-half years. The Lockyers think it must be assumed that the varying intensity in the solar activity in the course of the eleven-year sun spot periods has a direct influence on the air pressure and on the circulation of the atmosphere and in this way produces meteorological effects over the whole earth.

They found furthermore that these variations with a period of a few (3 to 4) years were not the only operative ones, but that the eleven-year and the thirty-five-year periods clearly influenced these shorter variations.

As above indicated, there occurred in 1894 or 1895 a remarkable break in the regularity of the curves of the two kinds of spectroscopic lines for sun spots and at the same time there occurred according to the meteorological publications of India irregularities in the precipitation there. Besides it is to be remarked, although not called attention to by the Lockyers, that for the years after 1890 both the summer and the winter curves of air pressure in Bombay run in opposite direction to the variations in the prominences, while the curve for April to September for Cordoba runs in the same direction as the variations of the prominences for these years. That is to say, the curves for the two stations from this time are relatively inverted.[1]

Later (1904-1908) Sir Norman and William Lockyer have extended their investigations to other regions of the earth and found that the two opposite types of air pressure variations have very wide extensions. The region in which the air pressure varies directly with the prominences extends over the whole Indian Ocean, Australia, South Africa, northwards over Arabia, Persia, North Africa, South Europe to Iceland and Greenland, and from there further over the region of Northern Canada to Alaska, while in South America, Western North Africa, the greater part of North America and the Pacific Ocean, as well as in east Asia, Siberia, and the most northerly part of Russia and of Scandinavia the air pressure variations are generally inverted with respect to the prominences. In one part of this region, as for example in southwest and middle Europe, most easterly Canada and other places, the variations run partly in one and partly in the other direction and the curves which express the variations in these regions have therefore a mixed type. As we shall see, this division of the earth into different regions where the variations have opposing directions agrees in its principal feature with Hildebrandsson's division of the earth's surface into different action centers where the variations occur inverted.

There appears to be a conflict between this result of the two Lockyers, that in India the air pressure in their three years' period varies directly with the prominences and, for example, in Siberia oppositely, and the proof which Chambers, Broun, Hill, Archibald, Blanford and others have furnished that in the eleven-year sun spot period the pressure in India varies in the opposite direction to

[1] It is, however, worth noting that the air pressure curves for Bombay in this time had in part a better direct agreement with the curves for the variations of the heliographic latitudes of sun spots.

the sun spots, while in Russia and Siberia it varies directly with them.

The two Lockyers call attention to the interesting circumstance that at separate stations it often occurs that while the variations over a long period of time follow one of the two types as at Bombay or Cordoba for instance, they may suddenly revert for another series of years to the other type, so that, for example, the air pressure might at first vary directly as the prominences and suddenly go over to the reversed type variation and after a lapse of some time again go back to the original type. This is explained by the Lockyers in this manner, that if a region with regular air pressure variations of one or the other type experiences in a series of years uncommonly great variations, the very high or very low air pressure prevailing over this region must be distributed to the surrounding regions of the earth and the boundary of the type of variations in consequence must be displaced so that stations which lie near the boundary of such a type of variation can on account of the extraordinarily great fluctuations in neighboring regions be constrained to change from one type to the other.

These important discoveries of the two Lockyers agree as, we shall see, in part with the investigations of Hildebrandsson. In the same direction points the already mentioned observation of Hann (1904), that in eighty per cent of the cases great positive air pressure anomalies in Iceland corresponded with negative air pressure anomalies over the Azores and that the greatest negative air pressure anomalies over Iceland in eighty-seven per cent of the cases coincided with positive air pressure anomalies over the Azores. This result which was reached from the observations of the years 1846 to 1900 strengthens the validity of the earlier conclusion which Hildebrandsson had drawn from the observational period 1874 to 1884 and agrees with the observations of the two Lockyers, according to whom the Azores belong to the region where the air pressure variations go in opposite direction to the prominences, while Iceland belongs to that region where the variations go directly with the prominences.

The result at which Prof. Bigelow arrived by his investigations agrees also in general with the observations of the two Lockyers. In his investigation of the year 1898, Bigelow found an agreement between the variations of air pressure in the United States and the variations in the sun spots and also in those of the magnetic force in Europe. He found that in the northwesterly part of the

United States the air pressure varied directly and the temperature oppositely as the sun spots and the magnetic forces. He also noted the shorter variations of a few years' period which he estimated at two and three-fourths years, and from this he concluded that there are four such periods in the eleven-year sun spot cycle. This is, as a comparison of the Bigelow curves with those of the two Lockyers shows, exactly the same short period that the Lockyers observed and whose duration they assigned at three and a half or 3.7 years. This well-marked period was also clearly shown in Bigelow's curve of 1894. The differences in the determination of its length are dependent upon the fact that the two Lockyers assume that there are three such periods in the eleven-year sun spot period. This was indeed the case in the time interval 1880 to 1890, which was the one principally investigated by them. Bigelow found also (1902, 1903) the same opposing relation which the two Lockyers had found between the air pressure variations in the different parts of the earth. He divided these variations into three kinds: First, those where the variation goes directly with the prominences; second, where it goes opposed to the prominences; and third, those in which now one and now the other type prevails and which he spoke of as the indifferent type. The charts which he gives illustrating the distribution of these different types of air pressure variations agree in general with the charts which the two Lockyers published in the following years.

Later (1908) Bigelow found that while the air pressure variations for the eleven-year period over the whole United States go in opposite direction to the sun spots and the prominences, it is otherwise with the short period of about three years, for in this they have the same direction as the prominences in the western United States and the Pacific Ocean, while they go in the opposite direction to the prominences in the states east of the Rocky Mountains. As already remarked, Bigelow is of the impression that the variations in the air pressure over the earth and particularly in the United States depend in great part on variations in what he calls "magnetic radiation" of the sun. This radiation influences directly, he thinks, the air pressure and the atmospheric circulation and thereby indirectly affects the temperature.

Dr. Richter (1902) compared five yearly smoothed curves of air pressure at different stations in Europe with curves for the sun spots, the Northern Lights, and the yearly variations magnetic declination for a series of years from about 1830 to about 1880.

These smoothed curves must therefore, it is to be expected, give best the longer periods of eleven years and upwards. For these he finds a well marked agreement between the curves for sun spots, etc., and those for air pressure at St. Petersburg, but less marked for the curves for other stations in more southerly latitudes in Europe. The air pressure variations in St. Petersburg in the eleven-year period go in the same way as the variations in sun spots, magnetic variations and Northern Lights and there is shown a tendency to the same direct agreement at several of the other stations.

Dr. Brask in Batavia (1910) has determined the variations in air pressure and temperature in Batavia for the period 1866 to 1909 and finds in both a complete agreement, with a well-marked period of about three and one-half years. The curves for pressure and temperature are completely similar. Variations in the temperature occur about six months after the corresponding variations in the air pressure. The curve for the air pressure difference between Batavia and Fort Darwin is similar to the air pressure curve for Batavia, only that it runs oppositely. The short period is, as he himself notes, the same which the two Lockyers have found, but from his curves it appears that the period is best defined as having a length of about three years only.

VARIATIONS IN WIND AND SUN SPOTS

As we have seen that the air pressure varies with the solar activity, it should be expected that the winds also vary thus. In the year 1872, Meldrum, the Director of the Observatory at Mauritius, noted that the cyclones in the Indian Ocean between the equator and 25° south latitude varied in number and intensity with the sun spots. He found that in three sun spots periods between 1847 and 1871 on the average seventeen cyclones in three years occurred in the neighborhood of the sun spot maximum, while near sun spot minimum in the same number of years only half as many cyclones occurred, or from eight to nine.

Shortly after this Poey showed that the cyclones in the Antilles have a similar periodicity. For the period of time from 1750 to 1873 he found that the maximum of cyclones occurred about one year after the maximum of sun spots, while the minimum of cyclones occurred about one year before the minimum of sun spots. The most decisive proof of the correctness of Meldrum's observations is furnished by the fact that the list of shipping losses of the marine insurance companies shows a similar variation to his assumed

variation in the probable number of cyclones, at least for losses in the low latitudes of the ocean.

Bigelow claimed (1894) that the storm tracks (that is to say, the tracts of high and low pressure) in the United States vary in their course with the sun spots in this way that the northerly storm track or northerly region of storms (" the North Low and the South High belts ") in the northern states and in southwest Canada were more northerly at maximum of sun spots and more southerly at sun spot minimum, while the southerly storm track (" the North High and the South Low belts ") varied oppositely (1894, p. 445). He found besides that the variations in these tracks not only showed the eleven-year sun spot period, but also showed the shorter period of approximately three years like the variations of the prominences. He believed himself also to have shown that within the sun's rotation period of 26.68 days coincidently agreeing variations occur in the terrestrial magnetic forces and in the prevalence of West Indian cyclones. But these short variations and the coincident agreement cannot be regarded as well substantiated without further investigations (see also Prof. Hazen's criticism 1894).

MacDowall has shown that in Greenwich in the spring, days with south wind are more frequent in years of prevalent sun spots than in years of few sun spots. It has also been found that in the interval 1850 to 1894, in the first three months of the year the number of days with north winds varies in the opposite sense to the number of sun spots. The number of days of frost in the first three months of the year in the neighborhood of London also varies in the same sense, that is to say, there are less frosty days and fewer days of north wind when there are many sun spots and vice versa.

Prof. Kullmer (1914, and see also Huntington, 1914, p. 253) has found that in a zone through the northerly United States and southern Canada, where the storms are most numerous on the average, the number of storms varies in almost direct agreement with the number of sun spots, in the same manner as has been shown for the tropical hurricanes. There are other regions, however, where the opposite is true. It appears as though the storms when there are few sun spots move in more widely scattered courses. If on the other hand the sun spots are more numerous the storms have a tendency to be concentrated along a few well marked paths, so that the storminess is confined to more or less definite regions within which it has a tendency to be concentrated.

Prof. Kullmer found also that in the interval from 1878 to 1887, and in the years 1899 to 1908, the storm course in the United States was displaced towards the south and west. He draws attention also (1914, p. 205) to the coincident displacement of the isogonals in the same way and that this indicates that the magnetic north pole has been displaced. He considers as probable the hypothesis, that the storm course is centered about the magnetic pole and moves with it.

VARIATIONS IN PRECIPITATION AND SUN SPOTS

The relation between the variations in the precipitation and the sun spots has led to many investigations since Meldrum in the year 1872 showed for several tropical stations that the rainfall varies directly as the sun spots so that a maximum of rainfall occurs at the maximum of sun spots and vice versa. Sir Norman Lockyer showed this also for several stations in Ceylon and in India. Investigations of Symons and Jelinek indicated the same conclusion, that more rain falls at sun spot maximum than at sun spot minimum, but it appeared that the periodicity is most marked and regular in the tropical regions. Hahn pointed out that in the period from 1820 to 1870 dry summers were most prevalent during the time of increasing sun spot numbers. On the whole the investigations on the relation between precipitation and sun spots are very conflicting and have led to more or less doubtful results. Meteorologists have here as in most similar investigations made the error of assuming that the same cause should everywhere produce the same effect, without taking sufficiently into consideration that the same cause at different places may act oppositely. Archibald and Hill have independently shown that the winter rain in India has the opposite course to that which Meldrum found. They obtained in fact a minimum at the maximum of sun spots and a maximum of winter rain about at the time of the minimum of sun spots. On the other hand, Hill seeks to show that the Indian summer monsoon rain has a great tendency to vary in coincidence with the sun spots in this manner that an excess of precipitation occurs in the first half of the cycle after the sun spot maximum and vice versa, but on the whole the curves show little agreement. Blanford came meanwhile to the conclusion (1889) that the precipitation in India on the whole gave no sure indication of a ten- or eleven-year period for the last twenty-two years.

For Europe, the connection between precipitation and sun spots has also been investigated. See Schreiber (1896, 1903), A. Buchan

(1903), and others. P. Schreiber (1896, 1903) found a probable eleven-year period in the precipitation at different stations in Europe, but with two maxima, one, two years after sun spot maximum, the other at the time of sun spot minimum, and with two minima, one coincident with sun spot maximum and the other three years after the sun spot minimum.

A. Buchan (1903) found a double period in the precipitation in Great Britain, so that a minimum occurs shortly after sun spot minimum and another shortly after sun spot maximum. The first and weaker maximum is much less marked in Scotland and west Europe than in southeast England where the principal maximum occurs nearer the sun spot maximum.

G. Hellmann (1909) has investigated the relation of variation of precipitation in different parts of Europe to the sun spot period and finds that there is no universally followed rule about it. In most cases of the stations examined by him there occur within a sun spot period two maxima of rainfall which occur about six or five years from one another. At the time of sun spot minimum there occurs at most stations a maximum of rainfall, but in consequence of the progress of wet and dry years from south toward north, in western Europe the maxima and minima of precipitation tend to be progressively displaced in the sun spot cycle.

The subdivision of the eleven-year period of rainfall Hellmann explains by an assumed double influence of the variation in the solar radiation during the sun spot period. First is a direct influence arising from the equatorial region and acting indirectly as an influence upon the place itself. Hellman proceeds from the assumption, now proved erroneous, that at the time of sun spot minimum there is a greater radiation of the sun that at the time of sun spot maximum. This increased radiation he thinks would act principally in the equatorial regions of the earth to produce an increase of temperature, evaporation and precipitation and thereby would increase the energy of the total circulation of the atmosphere. This equatorial influence would be delayed in reaching the higher latitudes. But on the other hand the direct influence on the precipitation in these latitudes themselves due to the sun spots would be considerably weaker than in the equatorial regions. The impulses derived respectively in the equatorial regions and in places of higher latitude would exercise together either a cumulative or an interfering action. It would be therefore conceivable, he thinks, that in one place the minimum of rainfall would be associated with maximum of sun spots, while in another place the opposite association would prevail.

VARIATIONS IN HEIGHT OF WATER IN THE LAKES AND RIVERS

It has been found that the middle European rivers give an indication of somewhat higher level of water at the time of sun spot maximum than at sun spot minimum. The Nile shows also a well marked maximum at the time of sun spot maximum.

The director of the Swedish Hydrographic Bureau, Dr. Axel Wallén, has, as already been stated, made valuable investigations on the height of the water in the great Swedish lakes. He has analyzed the periodic variations thoroughly and principally according to the method of consecutive means which Schreiber (1896) critically discussed. In his investigation in Wenern (1910), Wallén proceeds from the monthly means (the a-values). By consecutive means over twelve months, the yearly period is estimated. Thus he obtains b-values, which he finds give the average interval between the successive maxima or minima of something over three years. He found then c-values by successive means of forty b-values, whereby the approximately three-year period is eliminated. In a similar way he eliminates further possible periods of eleven and thirty-five years.

In order to study the single periods more accurately, Wallén computes the differences: $\alpha = a - b$, $\beta = b - c$, *etc.* He finds then for the height of the water in Wenern a period of thirty-two to thirty-three months with an amplitude of 76 centimeters (reduced). He also finds a double period of about twelve years, which is the sun spot period. Finally he discovers variations through a long series of years with an indication of the Brückner period. Concerning the sun spot period in the water level, Wallén finds a principal minimum nine months before the sun spot minimum and the prinicpal maximum two and a half years after the sun spot maximum. There is a weaker secondary maximum two years after the sun spot minimum and a more marked secondary minimum one year before the sun spot maximum.

In combination with these investigations upon Wenern, Wallén also studied the variations of precipitation and temperature in the surroundings. He determined a short interval variation of twenty-six months in the precipitation and of two years in the temperature. The eleven-year period is divided for the precipitation about in the same way as for the water level with the two amplitudes within the eleven-year periods about equally great. In the three-year period the extremes of the water level are approximately constant at a half year after those of the precipitation. The temperature shows

greater regularity. In the longer periods the two maxima follow the precipitation most closely (one to two years) after the sun spot extremes; the minimum, however, some years later. The corresponding extremes of the water level and the temperature come about a year later than that of the precipitation, but the temperature is again more irregular than the water level (see Johansson, 1912).

In a later article (1913) Wallén has exhaustively studied many years of variations of water level at Mälaren, the precipitation in Upsala and the air temperature at Stockholm in a similar way to that of his earlier paper of 1910. For the shorter period he finds:

Temperature, Stockholm. Length of period 26 months, Amplitude 2.8° C.
Precipitation, Upsala. Length of period 24 months, Amplitude 20 mm. per month.
Water level Mälaren. Length of period 30 months, Amplitude 40 cm.

The eleven-year period in all three cases is double featured as Wallén had found for the height of the water at Wenern. The two maxima in the height of the water in Mälaren are about equally great. The first maximum comes about fifteen months and the other eight months after the sun spot minimum. The amplitude is about 20 cm. For the precipitation at Upsala the difference between the two maxima is considerable, while the two minima are about equally intense. The extremes come some months earlier than the corresponding extremes in the water level, and the amplitude in the monthly values of the precipitation amounts on the average to 12 mm. Both for the precipitation and for the air temperature Wallén found similar three-year and eleven-year variations for other stations in north Europe, as well as for Upsala and Stockholm. He also found distinct traces of the Brückner period in these elements in Sweden.

GROWTH OF TREES

We must now refer to an interesting investigation of Prof. A. E. Douglass (1914). By accurate measurements of the rings of yearly growth of pines (Pinus ponderosa) in Arizona, and by careful comparison of the values found with the measured precipitation in this region in the last century, he conceives that he has established a basis whereby he can determine the variations in the precipitation in Arizona for the last five hundred years, employing for this purpose the measurements of the yearly growth for a number of selected and very old trees. In this manner he has obtained curves for the growth of the trees and for the precipitation in this interval of time.

He finds well-marked periods of 150 years,[1] 21 years, and 11.4 years. The last period, which corresponds to the sun spot period, is generally divided into two shorter periods and has two maxima and two minima. This is particularly the case in the earlier 250 years from about 1420 to about 1670. In the time from about 1670 to about 1790 these periods and also the eleven-year periods are less marked. In the time from about 1790 until now there are again two maxima and two minima within the eleven-year period, but the minimum in the middle of the period, that is, at sun spot maximum, is deepest; so that particularly during this time the growth of trees in Arizona and consequently the precipitation varied oppositely to the sun spots. Prof. Douglass gives also a mean eleven-year curve for the precipitation and for the temperature on the coast of California, which is 500 miles from the Arizona region, for the 50 years 1863 to 1912. This curve shows great similarity to the average curve of the eleven-year period for the growth of trees in Arizona during 492 years and also a similarity to the inverted average curve of sun spots for the eleven-year period, with the exceptions that the curves for growth and precipitation show two well-developed maxima within the eleven-year period.

By measurements of the yearly rings of growth of thirteen trees, at Eberswalde (in Germany) Douglass obtains a curve for the growth of these trees between 1830 and 1912 which corresponds well with the sun spot curve. Apparently in this region in Germany the growth of trees and the precipitation vary with the sun spots and not oppositely to them as in Arizona. Only in the sun spot period between 1890 and 1901 there is discordance and the variation goes inversely. In this period, however, we find in other meteorological relations similar discordances.

Douglass' curve for the growth of trees in Eberswalde shows also, though he does not mention it, a shorter period which agrees in part with the variations of the prominence curves and the magnetic curves.

Huntingdon in 1914 has also given measurements of the yearly rings of a great many old trees (Sequoias and Evergreen trees) in California and New Mexico in his investigations on climatic variations. His results point to the fact that great variations in precipitation occurred during the last 3,000 years. He pays little attention, however, to the periodicity in recent times.

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[1] See the period of three hundred years of Clough (1905) and of seventy-two years of Hansky (1894).

CLOUDINESS AND SUN SPOTS

The relation between the variations in the cloudiness and the solar activity is less accurately investigated. Klein has, however, shown that the highest clouds in the atmosphere, the cirrus, the cirro-stratus, and cirro-cumulus increase with the development of sun spots. Since these highest clouds produce the halos and similar phenomena around the sun and moon, such as mock suns, mock moons, and similar optical phenomena, it would be expected that these would be more prevalent at sun spot maximum than at sun spot minimum. This is actually the case, as is shown by the statistics of such phenomena over a considerable interval of time made by Tromholt. Even Tyco Brahe's diaries show that halos round the sun and moon are most prevalent in times of Northern Lights.

DUST IN THE ATMOSPHERE AND SUN SPOTS

Reference should be made here to the remarkable agreement found by Busch in the year 1891, between the variations of the sun spots and the variations in the polarization of the sky light. He found that the height of the neutral point (Arrago's point and Babinet's point) above the horizon at sunset rose and fell along with the frequency of sun spots, but the maximum and minimum of the neutral point came on the whole a year later than the maximum and minimum of sun spots. Earlier it was shown that after great volcanic eruptions, such as the Krakatao eruption, the recorded heights of the neutral points were increased. This depends upon the volcanic dust which is thrown out to the higher layers of the earth's atmosphere. From this we may conclude that at sun spot maximum the higher layers of the earth's atmosphere are filled with more dust than at sun spot minimum (see Arrhenius, 1903, p. 873).

THEORIES ON THE RELATION BETWEEN VARIATIONS OF THE SOLAR ACTIVITY AND METEOROLOGICAL VARIATIONS

After the above summary of the earlier investigations, it must be admitted that there is a dependence between the variations of the meteorological elements, such as the temperature and pressure, and the variations in the solar activity.

For the explanation of this dependence various hypotheses have been put forward. These may be divided principally into five classes, as follows:

1. The direct, that is to say, that the variations in the temperature of the earth are caused directly by variations in the outgoing radiation from the sun.

2. The variations in terrestrial temperature depend upon variations in the evaporation of the ocean and corresponding cloud formation and precipitation over the land.

3. Variations in terrestrial temperatures depend upon volcanic dust in the higher layers of the earth's atmosphere.

4. The periodic temperature variations depend upon changes of the ozone formation in the atmosphere.

5. Finally, the hypothesis that the variations, for example in the temperature and precipitation, depend upon variations of air pressure and circulation of the atmosphere, which again depend upon variations of the solar activity.

The first named theory, namely, that variations in terrestrial temperature are caused directly by variations in the same sense of the solar radiation, has been put forth by a number of investigators; for example, Chambers, Newcomb, Abbot and Fowle (in the year 1908), and we find it still in the more recent investigations of Arctowski and in part Huntington and many others.[1] Remembering Lockyer's spectroscopic investigations of the sun—in which he showed with some certainty that the solar surface is warmest at maximum of sun spots—it is surprising that it should still have been thought that increased temperature of the earth at sun spot minimum could be attributed to an increase in the output of solar radiation. However, it was still conceivable that even if the real temperature of the sun increased it might be that the output of solar radiation did not correspondingly increase. It might be considered perhaps that formation of clouds or dust in the solar corona hindered the outgoing radiation of the sun. But in the pyrheliometric and bolometric measurements which were made by Langley and by Abbot and Fowle after 1902, first in Washington and after 1905 on Mt. Wilson in America, and after their investigations on Mt. Whitney in America, and in Algeria, it must be considered as having been shown that the solar radiation which reaches the outside of the earth's atmosphere experiences no variations which correspond directly with the observed variations in the atmosphere at the surface of the earth. These measurements indicate plainly that the "solar constant" (that is, the solar radiation outside of our atmosphere) is considerably greater near the sun spot maximum than near the sun spot minimum. Although the measurements do not

[1] Huntington, however, later (1914-a) came to the view that the variations in the solar activity cause first variations in the storminess, as we shall later refer to more at length.

show exact agreement they show at least with certainty that the relation cannot be inverted.[1] These measurements lead furthermore to the remarkable discovery which was confirmed by coincident observations on Mt. Wilson and in Algeria that the radiation of the sun outside our atmosphere varies considerably from time to time within a few days interval, sometimes increasing, sometimes decreasing. Hence our sun is in a high degree similar to the other variable stars which we see in the heavens, like the star Myra. According to these measurements the theory that the observed eleven-year variation in the air temperature on the earth's surface follows directly corresponding variations in the output of solar radiation must be definitely abandoned.

It was particularly Blanford who advanced the second theory, that depression in the terrestrial temperature at sun spot maximum depends upon increased solar radiation, which produces an increased evaporation of the ocean and thereby an increased formation of clouds on the land, which in its turn again diminshes the solar radiation on the continental surfaces and causes a fall of temperature. Besides this the re-evaporation of the increased rainfall would further diminish the temperature. That this theory—which seems so reasonable—has not so general application as was to be expected must be partially explained by the fact that investigation of the variations in the cloudiness show that these do not have an exact relation with the variations in the sun spots, such as the theory assumes. But there is yet another difficulty. According to this theory one would expect that the surface temperature of the ocean, particularly in the tropical regions, would be highest at sun spot maximum and lowest at sun spot minimum, but this as we have seen, is not the result of our collected observations. On the contrary our temperature tables and temperature curves show for different parts of the ocean the inverse relation, that is, lower temperature at sun spot maximum and high at sun spot minimum. It may be recalled,

[1] The following values (in calories) of the solar constant were obtained on Mt. Wilson:

1905	June to Oct.	1.956		1910	May to Nov.	1.921
1906	May to Oct.	1.942		1911	June to Nov.	1.923
1908	May to Nov.	1.936		1912	June to Aug.	1.940
1909	June to Oct.	1.918				

According to this there was a maximum in 1905 which could correspond to the sun-spot maximum, but on the other hand there was a minimum in 1909 and a secondary maximum in 1912.

for example, that the variations in the temperature of the surface and of the air in the middle of the Indian Ocean (see figs. 55, X-XI) agree with the variations of the air temperature at the tropical stations of Mauritius, Batavia, and others (see figs. 68, 71). This shows that the explanation of the general phenomena of temperature variations of the earth which we have referred to is untenable. We shall later return to this consideration.

With regard to the theory of Abbot and Fowle and of Humphreys, that the extension of volcanic dust in the atmosphere has an important influence on variations of the temperature of the earth's surface, the curves given by these authors of the pyrheliometric measurements of the heat obtained from the solar radiation at the surface of the earth do not fully prove their hypothesis, since the curves have only a small similarity with the curve of the variations in the yearly temperature of the earth. This latter has indeed a very great similarity with the curve of sun spots. However, it must be admitted that these authors have made it probable that the volcanic dust which is distributed in the atmosphere, particularly at times of the most violent volcanic eruptions, acts in such a way that the temperature at the earth's surface is depressed, and according to Humphreys' opinion it may be even possible that this effect was in former times very considerable. But the influence is not sufficient in order to explain the continuous and often great variations in the climatic temperature of the earth.

Humphreys' theory that the eleven-year variation in the temperature of the earth, which is associated with sun spots, depends on variations in the ozone formation in the atmosphere, assumes a corresponding variation in the relation between incoming radiation and outgoing radiation at the earth's surface, in other words, the corresponding variation both in the daily and the yearly temperature amplitude of the earth. But as we shall see later, such a variation in this amplitude cannot be proved with certainty, at least not such as the theory assumes.

Finally we come to those theories according to which the variations in the solar activity produce primarily variations in the air pressure and in the circulation of the atmosphere which in their turn influence other meterological elements. This view, which has been advocated particularly by the two Lockyers and by Bigelow would appear reasonable, but hitherto has had comparatively little support. It agrees in its principal features with the results to which we have arrived, and we shall refer later to this theory.

SUPPLEMENTARY NOTE

Recently we have had opportunity to consult Huntington's treatise entitled "The Solar Hypothesis of Climatic Changes" (1914-a), which contains the very valuable investigation by Prof. Kullmer on variations in the storm tracks in America and the considerations based thereon. Like Prof. Bigelow previously, Prof. Kullmer found that the great northerly storm track in the United States is displaced further to the north at maximum of sun spots, while the less important southern storm track is displaced further south. He finds also that the frequency of storms in the United States is greatest at sun spot maximum and least at sun spot minimum. In consequence of the motion of these storm tracks there is a bow-shaped region in the middle states in which the storminess varies alternately. That is, it is greatest at sun spot minimum and least at sun spot maximum. In comparisons with the variations in the storm tracks and the frequency of storms Kullmer and Huntington have used only the sun spots and no other sign of the variations of the solar activity, such as the prominences and the variations in the magnetic elements on the earth. They have therefore not noticed that the numbers which they give for the storminess and which agree somewhat badly with the variations in the sun spots, that these numbers, I say, give distinct indications of shorter periods than the eleven-year period which they have alone considered.

The tables of storminess published by Huntington (1914-a, p. 502) give within the sun spot period three shorter well-marked periods which he has not called attention to, for he believes that the apparent irregularity and disagreement with the numbers of the sun spots is due to imperfect observations. The curves given in his figure 9 show this. But the disagreement between the curve of storminess and the curve of sun spots causes him so great difficulty that he explains that the problem must be provisionally unelucidated. He has not noted that these storm curves of Kullmer have the same short period of about three years which Bigelow found in the variations of the storm tracks and in the variations of air pressure and temperature and which the two Lockyers and others have noted in the air pressure.

In figure 64 we give Kullmer's curve (*St*, according to Huntington) for the storminess in the northern United States, together with curves for the prominences (P according to the observations in Rome and Catania), for the disturbances of the magnetic element at Potsdam (M) and for the sun spots (S). The storm curve shows

three or four short periods in the first sun spot period of the figure, four periods in the second, and three in the third sun spot period. The last three short periods fall very well with corresponding periods in the variation of the prominences and particularly in the disturbances of the magnetic elements. The sun spot curve shows also an indication of the same three periods. In the sun spot period, 1889 to 1902, the agreement between the storm curve and particularly the magnetic curve is not very good. In the sun spot period of 1878 to 1889 the storm curve and the prominence curve agree, but the variations in the prominences come later on than the variations in the storminess. At the storm maximum in the year 1880 there is nothing corresponding in the other curves. On the whole

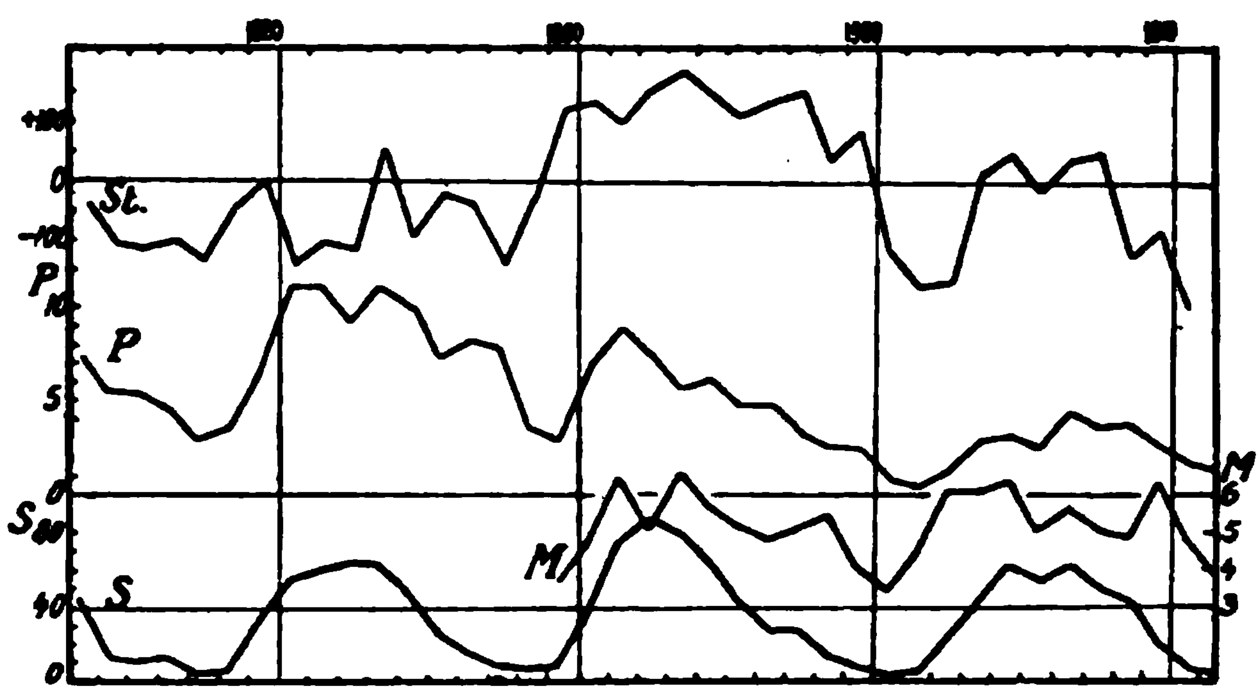


FIGURE 64. St: storminess in the northern United States according to Kullmer. P: average daily number of prominences according to the observations in Rome to 1898 and Catania. M: degree of disturbance of the three magnetic elements at Potsdam. S: observed relative sun spot numbers according to Wolfer.

the storminess in this eleven-year period appears to be much less than it should be in comparison with the prominences and sun spots.

Kullmer's investigations on the variations in storm tracks and storminess have furthermore led Huntington to the view that the variations in the storminess on the earth are the cause of the variations of the temperature on the surface of the earth. He assumes that an increased storminess would cause the temperature to fall, particularly in the warmer regions of the earth, because the warm air from lower latitudes would be carried by the storms to higher latitudes and there would rise above the colder air at the earth's surface. This colder air would then displace the warmer air at lower latitudes and partly by vertical circulation the warmth continually developed at the earth's surface would penetrate to the higher layers of the air. Huntington considers that this influx of greater quanti-

ties of heat into the higher layers of the air does not tend to affect them so much since they will pass on these quantities of heat into outlying space by increased outgoing radiation.

In this way Huntington thinks that the equatorial and subtropical regions may lose heat and that thereby the temperature may be lowered by increased storminess at maximum of sun spots. In higher latitudes and especially in polar regions no such sinking of the temperature would follow. In those regions perhaps no great difference occurs between maximum and minimum of sun spots, or the relation may be even inverted so that an increase of temperature may occur at maximum of sun spots.

As the reader may see, Huntington's view of the cause of the variations in the air temperature of the earth agrees with that which Bigelow had previously advanced in so far as he attributes the principal cause to the air circulation. Other investigators, particularly the two Lockyers, as we have said in our summary of earlier investigations in this matter, have come to the same conclusion. We see also that Huntington's conclusions have some similarity with ours, although we had not in fact thought of the frequency of storms, but more of the increase or diminution of the air circulation in general. Furthermore, we had in mind a somewhat different method of correlation between variations in the air circulation and variations in the temperature of the atmosphere.

Kullmer has called attention in his work to the possibility of a correlation between the storms and the terrestrial magnetism. He maintains that there are three storm centers which correspond to the three magnetic poles. In the southern hemisphere there is only one magnetic pole and the cyclonic storms circulate about it in the vicinity of 60° south latitude, not concentrically about the geographical pole, but about the magnetic pole. In the northern hemisphere, the most important storm track of the world extends almost exactly concentric with the magnetic North Pole in northern Canada, thence across North America, over the Atlantic Ocean to Scandinavia, and the storm track in the Atlantic Ocean follows almost exactly the lines of equal magnetic total intensity. In Siberia there is another secondary magnetic pole and corresponding to it there is a third storm track which has its middle point in Japan.

XI. THE VARIATIONS IN THE METEOROLOGICAL RELATIONS IN THE TROPICS AND THE NORTHERN REGIONS

From Köppen's curves for the mean temperatures in different years in different regions of the earth it is apparent that in many instances very distinct relations occur between the sun spot periods

and the temperature variations in our atmosphere at the earth's surface. However, the eleven-year sun spot period in the temperature curves is to a great extent overshadowed by the shorter interval variations.

RELATION BETWEEN THE TEMPERATURES OF DIFFERENT REGIONS OF THE EARTH AND SUN SPOTS

In order to bring out the longer periods more clearly we have smoothed the yearly means given for different regions of the earth by

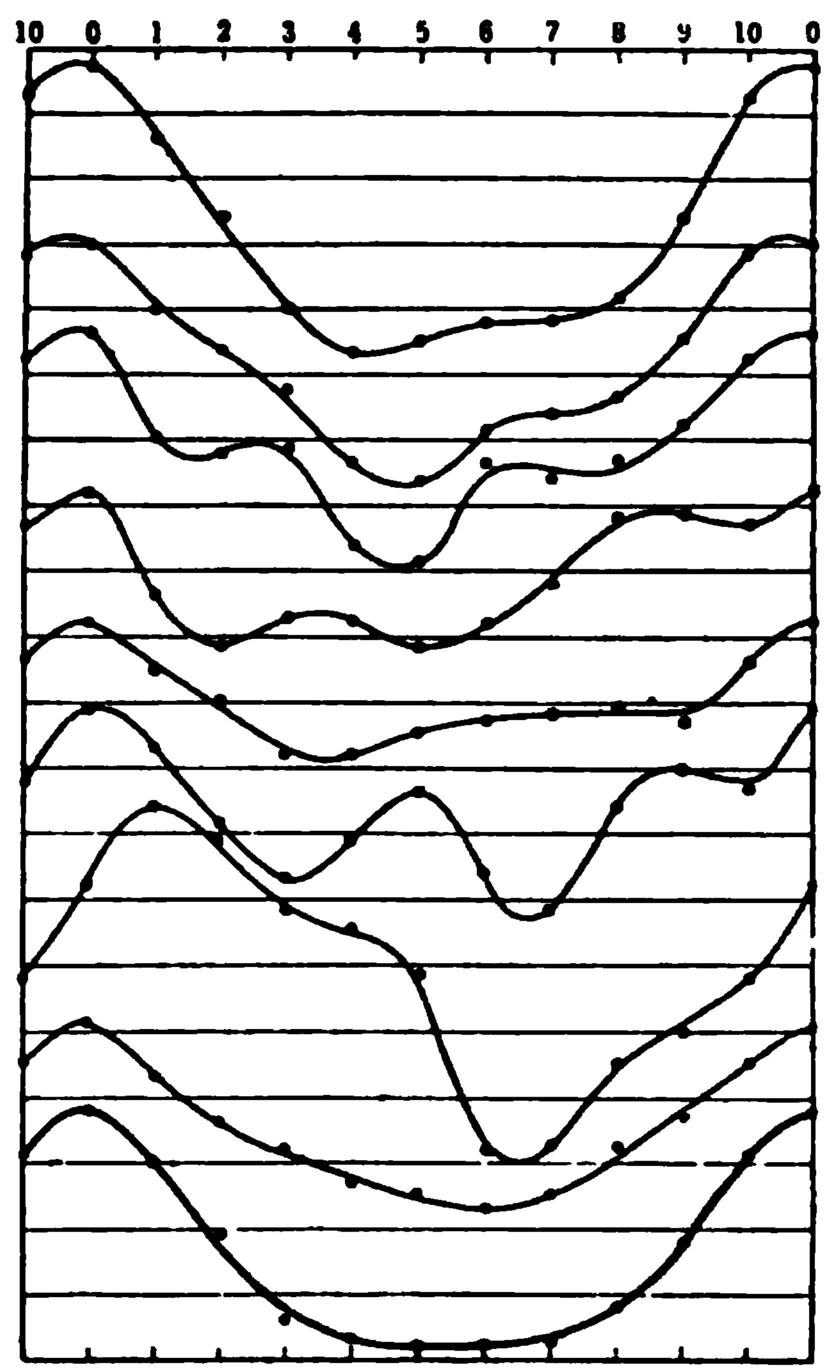


FIGURE 65. Average variation of the air temperature during the sun spot periods in the time 1811 to 1910 according to Köppen (1914).

Köppen which we took from Mielke's temperature series published in his paper of the year 1914. We have first taken consecutive three-year means and from them as a basis eleven-year means. These are shown in the curves of figure 66. At the top there is given in a full drawn curve the smoothed relative numbers of sun spots according to Wolfer's tables. The dotted curve gives the consecutive eleven-year means of the smoothed relative numbers. The other full drawn curves show the temperature variations in different regions of the earth smoothed as three-year means. The

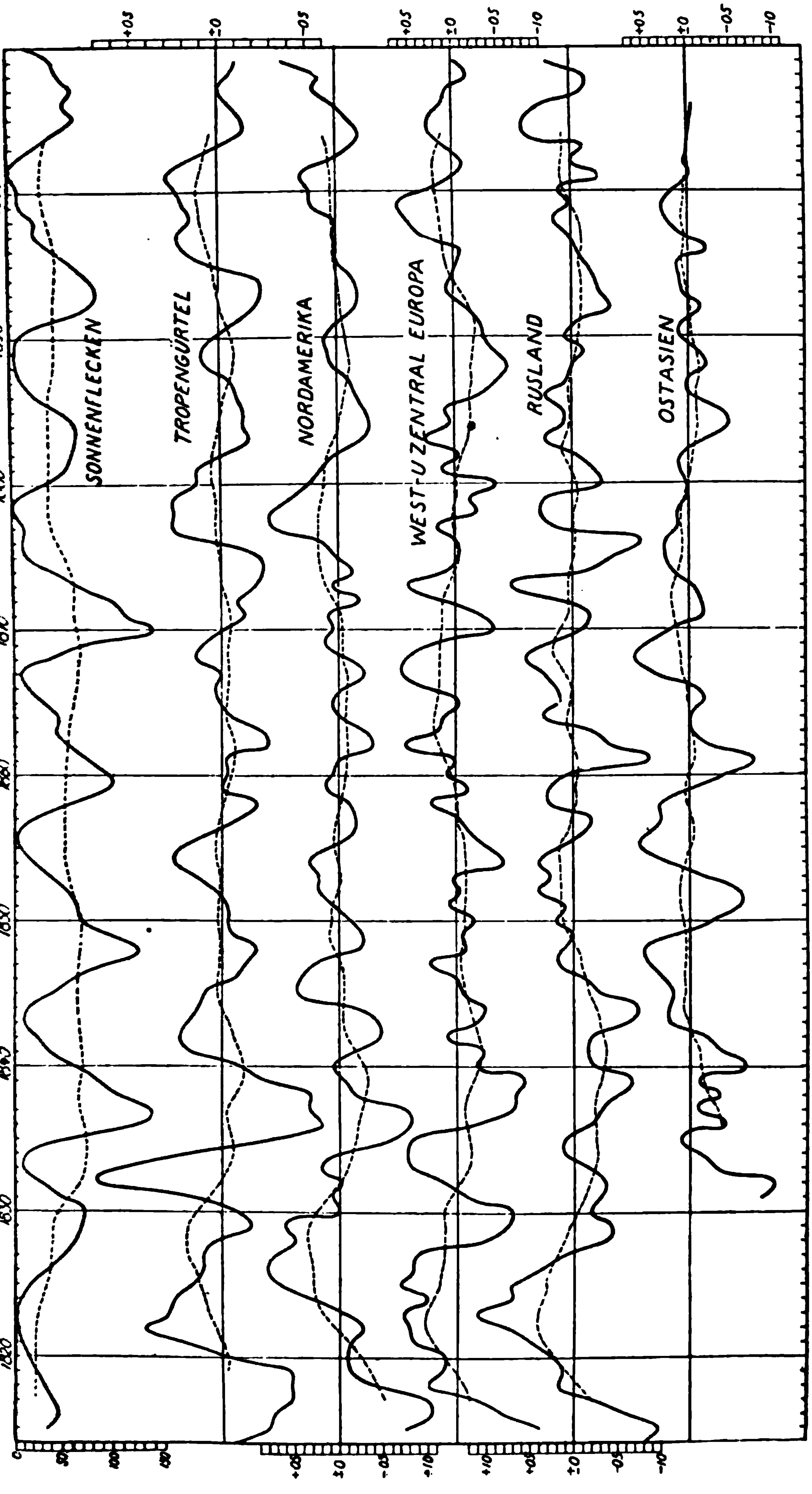


FIGURE 66. Curves for three-year (full-drawn lines) and eleven-year (dotted lines) smoothed temperatures of the air for different regions of the earth according to Köppen's and Mielke's tables.

dotted lines show the corresponding values with successive eleven-year smoothing.

Between several of these curves and the inverted sun spot curve there is an extraordinary agreement. Particularly the curves for the tropics, for North America, and in a less degree those for eastern Asia are of this character. The variations in the curve for eastern Asia appear to be displaced a couple of years in relation to the sun spot curve. In general it holds that a maximum of sun spots corresponds to a minimum of temperature. The reader should note that the scale of the sun spots increases downwards, while the scale of the temperature curves increases upwards.

The other curves show many small variations and in several cases there is a strongly marked tendency to a half sun spot period in the temperature variations. This is shown particularly well in the curve for Russia where a minimum of temperature occurs approximately at maximum of sun spots, but also a considerable minimum at the minimum of sun spots. This is shown also in figure 65 which is taken from Köppen's paper. The shorter periods are of course for the most part removed from our curves in figure 66 in consequence of the smoothing.

In figure 67 we have compared the sun spot curve (S) with the smoothed temperature curve for the whole earth (curve *a*) by consecutive three-years smoothing from the values given in Mielke-Köppen tables. The agreement between these two curves is very great and the existence of sun spot periods in the variations of the air temperature upon the earth cannot be doubted. We have studied the correlation between these two curves in this way: we have determined the average temperature value which corresponds to certain sun spot numbers. The means of these values we have given in curve *c* in figure 67. This curve shows therefore the temperature distribution which we should expect dependent upon the number of sun spots.

The difference between curve *a* and curve *c* is plotted in the curve *a-c* which, however, shows considerable variations outside of those which correspond to the simple sun spot period. As the reader will perceive, there is a tendency in this curve to show two small variations within each of the great simple sun spot periods.

In order to pursue the question of what relation exists between the variations of the sun and the meteorological phenomena upon the earth, it is of importance to study the meteorological elements separately. We have therefore collected a great series of investigations

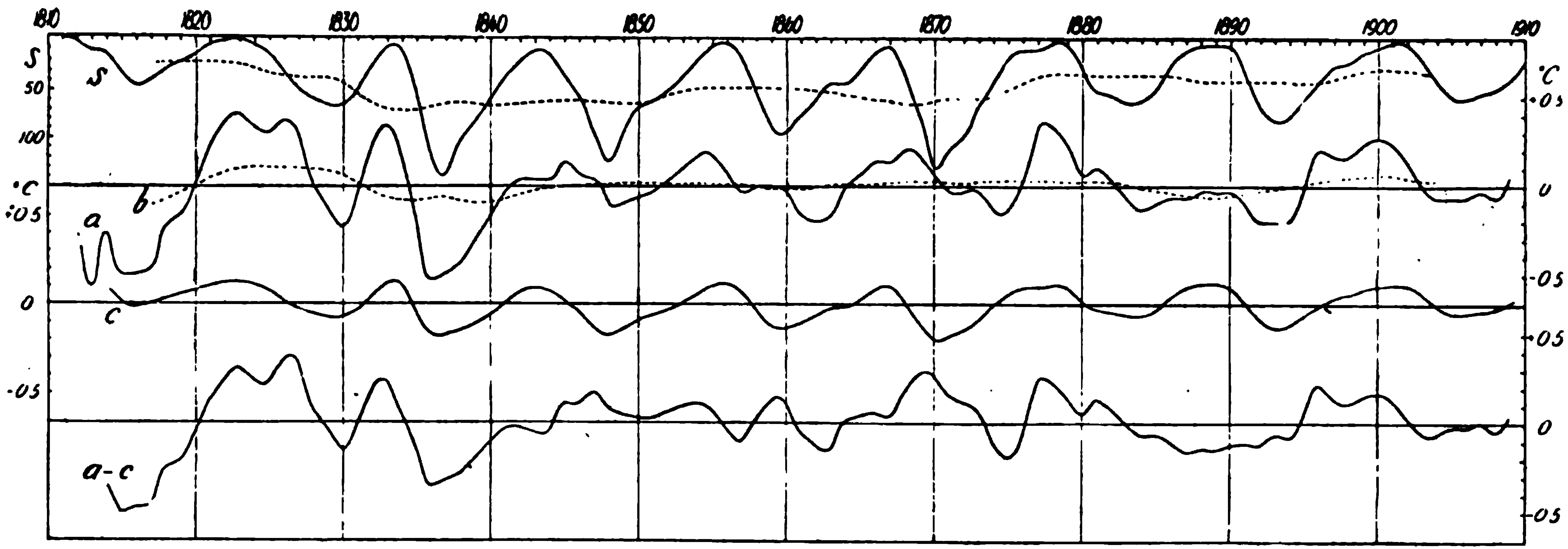


FIGURE 67. S: relative number of sun spots according to Wolfer's tables of smoothed values. The dotted curve represents these values after smoothing by consecutive eleven-year means. *a:* temperature of the whole earth according to consecutive three-year smoothing $(b^1 = \frac{1}{3}(a+b+c))$. *b:* continued eleven-year smoothing of the same values: $(f = \frac{1}{11}(a^1 + b^1 + \ldots + k^1))$. *c:* curve for the correlation between curve *a* and curve S. *a-c:* difference between the values of curve *a* and those of the curve *c*.

of meteorological phenomena in different parts of the earth. As was to be expected, these show that in high latitudes the relations are more complex and are connected with more frequent and greater fluctuations than in the tropics where the phenomena proceed more

FIGURE 68. Curves of the meteorological elements at Batavia. *a*-curves indicate the directly observed monthly means. *b*-curves represent the mean of the foregoing in consecutive twelve-month smoothing. *c*-curves, continued consecutive twenty-four months smoothing. S, smoothed relative sun spot numbers. R, P. C, successive twelve-month means of the daily numbers of prominences according to the observations in Rome (R) Palermo (P) and Catania (C). Scale on the right, 100 equals 10.0.

simply and are more easily studied. It is therefore most natural to begin our investigations with the tropics.

VARIATIONS OF METEOROLOGICAL ELEMENTS IN BATAVIA

Among the tropical stations we have studied first Batavia, where very complete satisfactory investigations of meteorological elements have been made for a long series of years.

In figure 68 we give the curves for the variations of the different meteorological elements in Batavia. There are three kinds of curves: *a*-curves which show the variations in the directly observed monthly means; *b*-curves in which these monthly means are smoothed by taking twelve-monthly consecutive values; and *c*-curves which are smoothed by taking consecutive twenty-four-monthly means.

By comparison of these different curves there is found a great similarity even in many details. We shall consider particularly the *b*-curves. It appears that the greater variations are repeated in all the curves, but so that the temperature variations occur somewhat later than the air pressure variations and the variations in other elements. That the variations in air pressure occur often several months before the variations in temperature is seen in many instances in the *a*-curves, see for instance the years 1877 and 1878, where we find three well marked maxima in air pressure which occur several months later in the temperature.

It is natural to think that variations in air pressure call forth variations in the cloudiness and thereby again variations in precipitation and in the daily temperature amplitude. Variations in the cloudiness will obviously call forth variations in the temperature of the air. A great cloudiness at a station like Batavia in the tropics is accompanied by low temperature. In our figures the scale of cloudiness has been given with increasing values downwards, while for the temperature the scale increases upwards. Changes in the temperature come in consequence of the earth's capacity for heat somewhat later than the changes in the cloudiness. But these are instantly accompanied by changes in the daily temperature amplitude. The consequence of this is that the variations in the daily temperature amplitude as a rule precede somewhat the variations in the average temperature of the place, as is shown by comparison of our curves in figure 68. We have drawn a *b*-curve for the mean daily temperature amplitude. This shows on the whole the same variations as the other curves. It may be of particular interest to note that the well-marked minimum which we found in the year 1904 for the surface temperature in the Atlantic Ocean is also shown in all the curves of meteorological elements in Batavia except in the curve for the wind velocity and for the daily temperature amplitude.

As the reader will see, the *b*-curves and the *c*-curves follow one another on the whole. Apart from some individual exceptions the principal variations occur in both curves in common, which indi-

cates that the two-year period plays no great part in the conditions at Batavia. Taking the intervals in months, for example between the maxima in a long series of years in the different curves, one finds an average interval between them of 32 to 33 months, which corresponds to a quarter of a sun spot period.

Comparing these curves for meteorological relations with the sun spot curve (S) which stands lowest in the figure, we see as a rule that at minimum of sun spots a maximum of air pressure, temperature and of daily temperature amplitude occurs and the

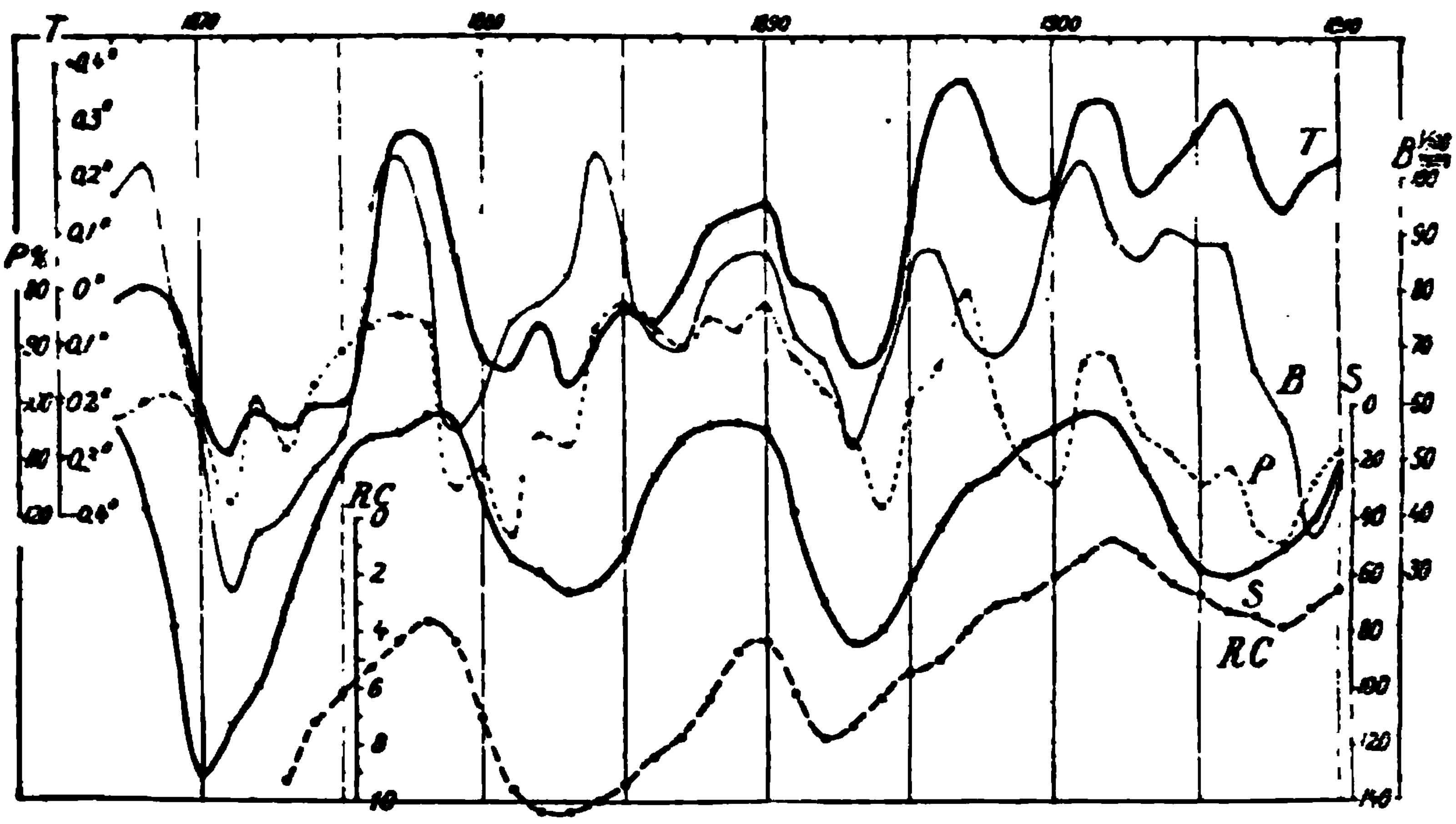


FIGURE 69. Batavia. Curves show successive three-year means of temperature, (T); air pressure, (B); rainfall, (P); sun spots, (S); prominences, (RC); according to the observations in Rome up to 1898, and in Catania.

minimum of cloudiness and precipitation. At maximum of sun spots there occur on the whole similar but secondary maxima and minima in agreement with the above mentioned quartering of sun spot periods. The short periods of about three years agree partially with corresponding periods in the prominence curves R, P and C. We shall speak later of this again.

The correspondence between variations in the sun spots and in the temperature and air pressure in Batavia is particularly well seen if one takes the separate yearly means of meteorogical elements by consecutive three-year intervals. The result of such a computation is given in figure 69, where the curves of air pressure and temperature are given with increasing scale numbers upwards and the curve of sun spots with increasing scale numbers downwards. The eleven-year period of meteorological phenomena comes very plainly to view, but it is to be noted that there are indications of a

division of this period into two. The quarterly division is of course eliminated by the process of smoothing.

The observational material at Batavia continues from the year 1866 to 1910, that is, through four sun spot periods. We have taken the mean value for these four periods and the results are given in figure 70, where the sun spot curve S is obtained by taking the mean of the four eleven-year periods. Corresponding curves of air temperature T, air pressure B, and precipitation P for Batavia

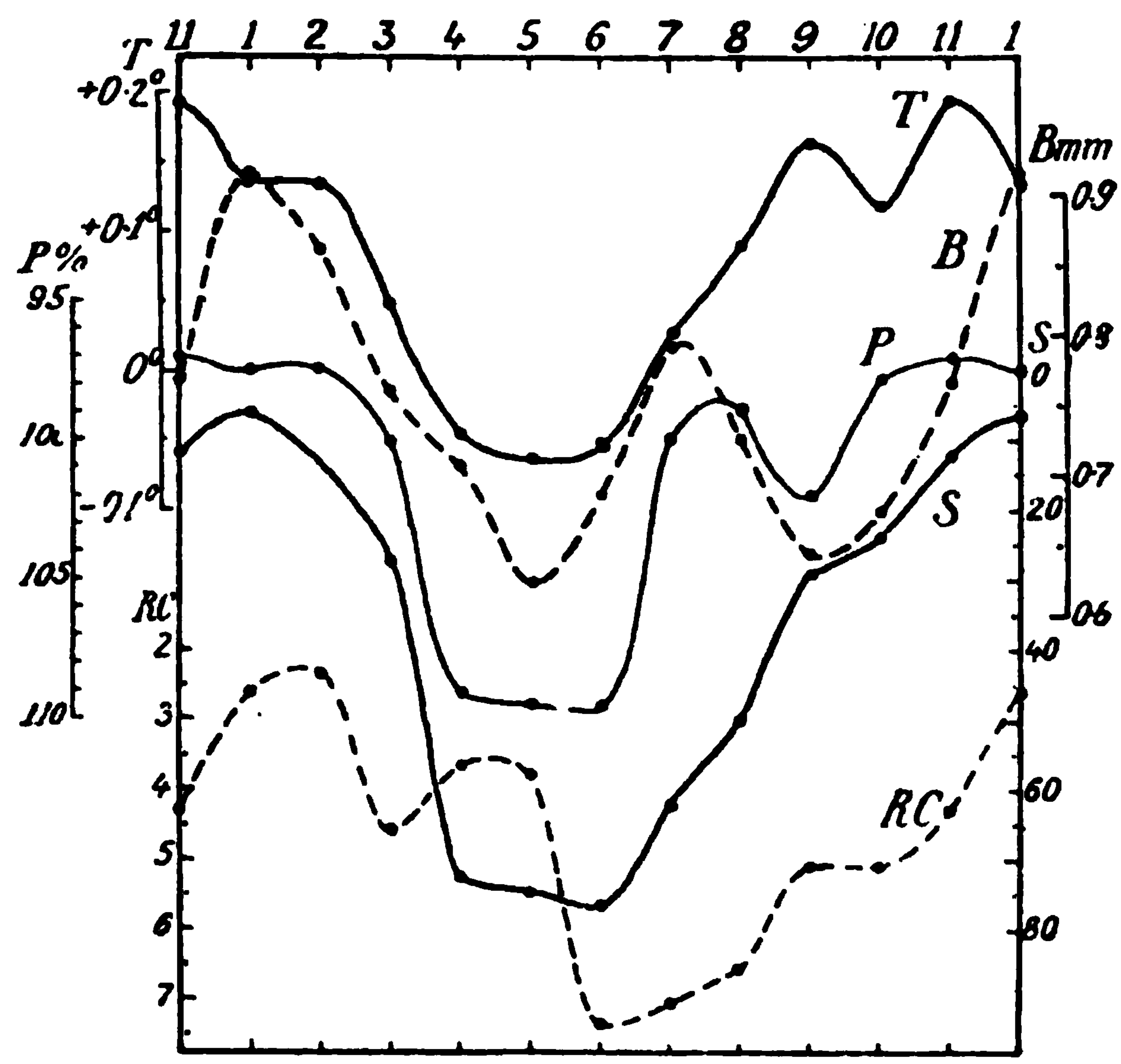


FIGURE 70. Batavia. Average variations in the air temperature, (T): air pressure, (B); rainfall, (P); sun spots, (S); prominences, (RC), during the sun spot periods in the time 1866 to 1910.

are given. The prominence curve R C is obtained by similar computation for the time interval 1872 to 1910.

From these two figures it may be seen as we have already found that the air pressure and other phenomena on the whole are earlier with their variations than the air temperature. In figure 70 the division of the eleven-year period into two halves is distinctly shown for all meteorological elements.

The analysis of meteorological elements in Batavia shows therefore distinctly variations with 11, $5\frac{1}{2}$ and $2\frac{3}{4}$ years, therefore the whole, half, and quarter of the sun spot period.

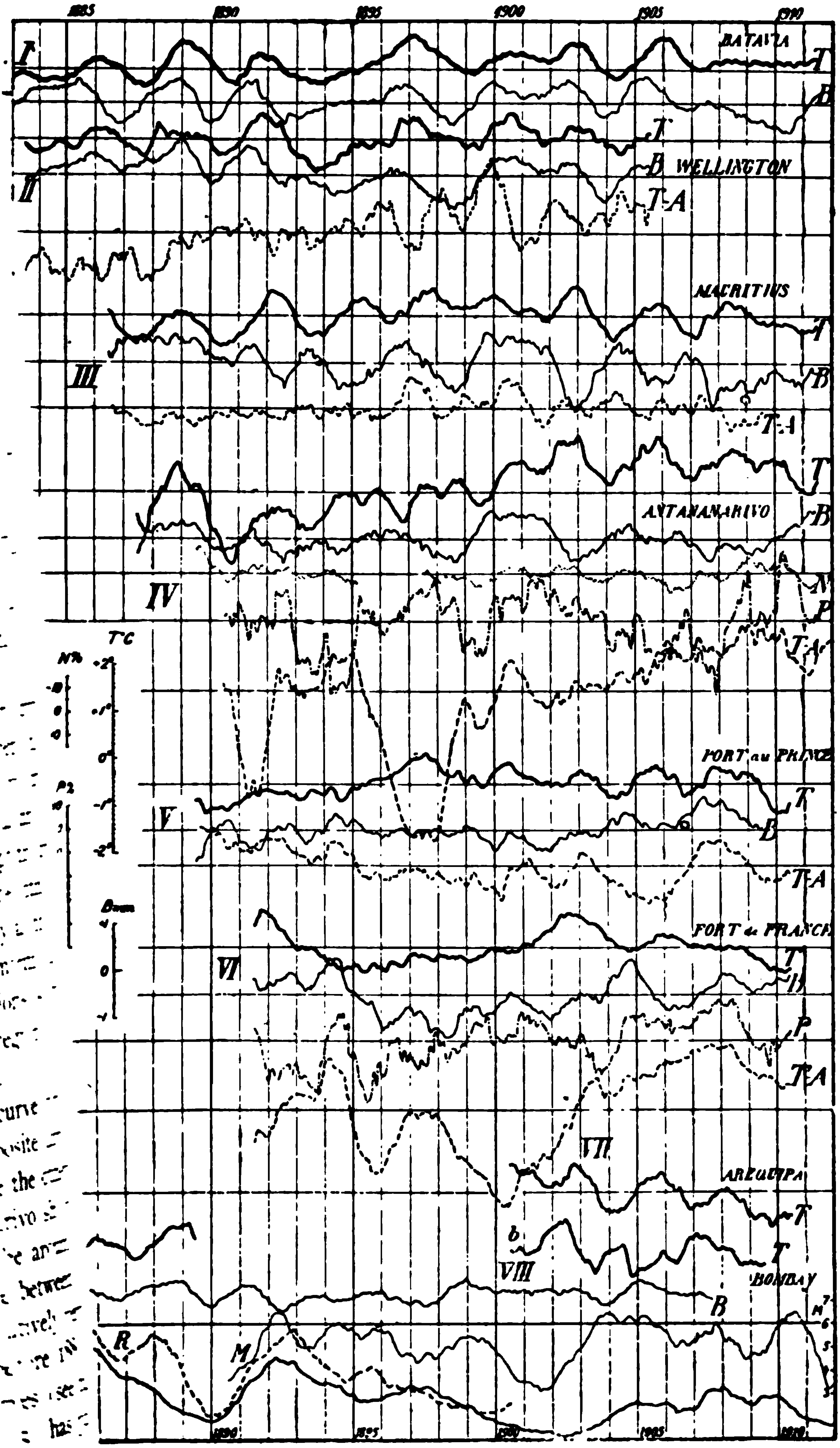
TEMPERATURE VARIATIONS AT DIFFERENT STATIONS IN THE TROPICS AND OTHER REGIONS

We have also studied the meteorological variations in a series of other tropical stations and have given the results of the investigation in figure 71. The curves have the following significance: T for temperature, B for air pressure, P for precipitation, N for cloudiness, and T-A for temperature amplitude. At the top of the figure the temperature and pressure curves for Batavia are repeated. In the remainder of the figure are given curves for Wellington in south India, Mauritius, Antananarivo in Madagascar, Port au Prince, Haiti, Fort de France, Martinique, and finally Arequipa, Peru, and Bombay. The temperature curves VIII *a* and *b* for Bombay are taken from Arctowski's paper, 1912 and 1915. The scale is not exactly the same as the scales of the other curves, but very nearly the same.

Considering first the temperature curves (heavy lines) we see a close similarity among them except that for Bombay after 1900 (curve VIII-*b*). As an example we may note especially the minimum in the years 1903 and 1904 and the maximum in 1905 and 1906, which are found in all except the curve for Bombay and almost exactly at coincident times. The other well marked maxima and minima are found almost exactly at the same time in all the curves or at the most with only a two-month phase displacement. We find, in other words, the same variations, so that for example the 2¾-year period is found in different regions of the earth as it is found in Batavia and Arequipa, Peru.

However, the temperature curve for Bombay in the years 1900 to 1909 runs in exactly the opposite direction to all the others. This is the more surprising because the other stations, Batavia, Wellington, Mauritius, and Antananarivo show at the same time complete agreement. All the stations lie around the Indian Ocean. Moreover the distance for example between Bombay and Wellington ..
the south point of India is relatively v
for Bombay for the years before 18
agreement with the other curves (see

Arctowski (1912, 1914, 1915) has
found by twelve-monthly consecutive
meteorological stations in different
72 and 73 we have repeated par
some of the curves obtained in
tribution of temperatures in t



71. Curves for different meteorological elements with consecutive
›nth smoothing. T: air temperature. B: air pressure. A: daily
re amplitude. M: quantity of cloudiness. P: rainfall. M: dis-
of the three magnetic elements at Potsdam, scale on the right. R:
iber of prominences according to the observations in Rome. PC:
to the observations in Palermo and Catania. Twelve-month
.

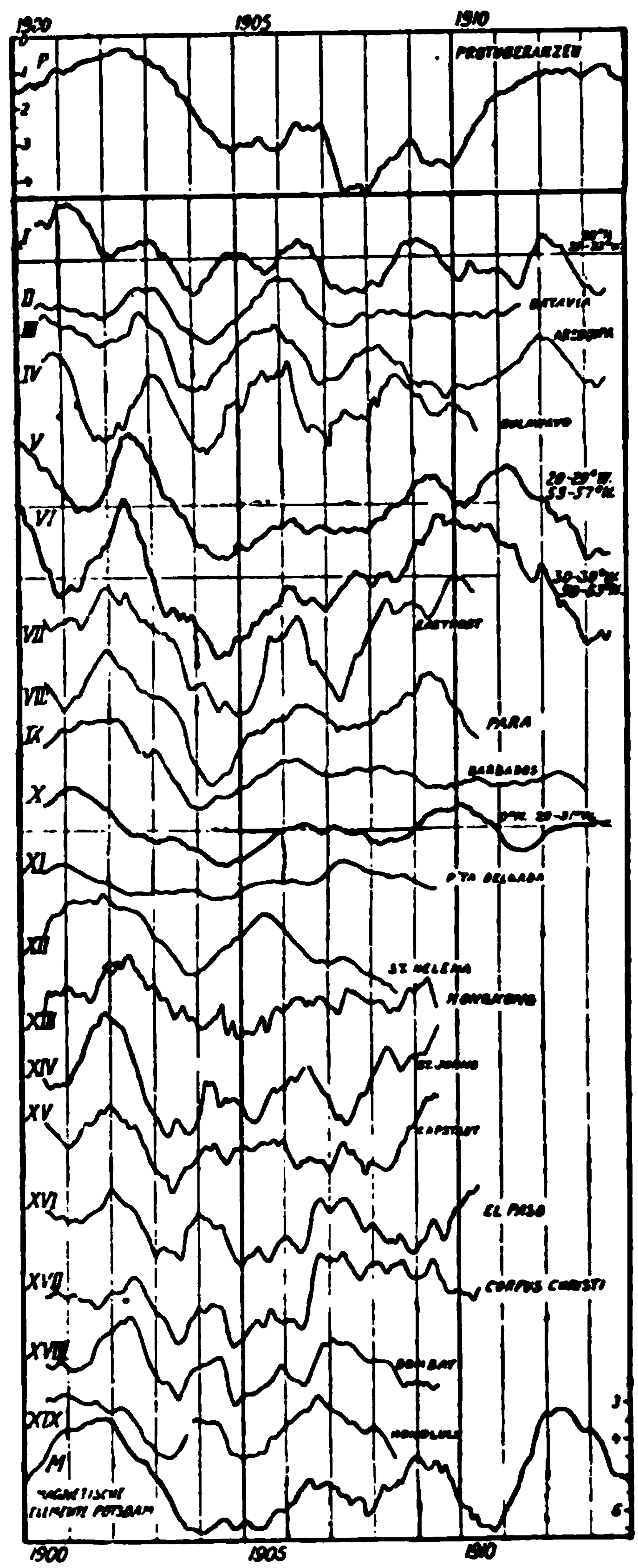


FIGURE 72. Curves in consecutive twelve-monthly smoothing for the air temperature (according to Arctowski), surface temperature (I, V, VI, X). P: monthly mean of the daily number of prominences according to observations in Catania. M: degree of disturbance of the three magnetic elements in Potsdam. Curves P and M are inverted. All curves indicate the consecutive twelve-month smoothed means.

Dutch fields (see fig. 72, V and VI, fig. 73, IX and XIV). We also show the results in the fields of the International Central Bureau (see fig. 72, I and IX) and also similar curves for the whole of Norway and for meteorological stations in the western United States on the Pacific Ocean. As the reader will see, there is an undeniable coincident agreement between many of these curves taken from such different regions of the earth. But at the same time it is also

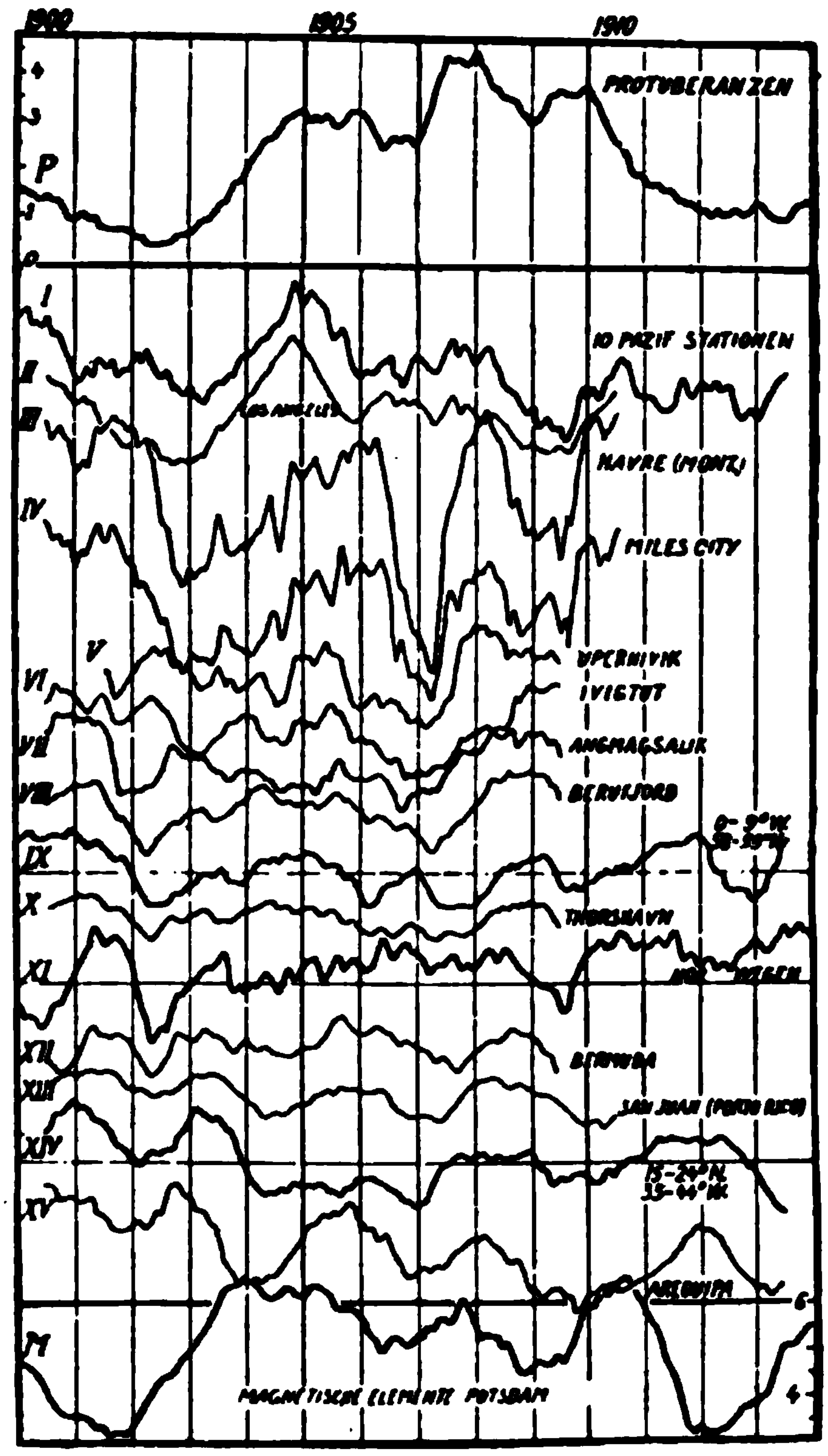


FIGURE 73. Similar curves to figure 72 for the air temperature (mostly according to Arctowski) and the surface temperature (IX, XIV).

apparent that the curves belong to more or less marked types. For example observe the well-marked type which governs the surface temperatures of the ocean in the fields of 20° north latitude and 20° to 22° west longitude shown in figure 72, I. Also the type for the air temperature at Batavia, Arequipa, Bulawayo and other places shown in curves II to IV. This is the same type which is found in all of our tropical stations in figure 71, as Batavia, Wellington, Mauritius, etc.

There is another type which is characteristic of the more western Danish fields at 20° to 29° west longitude and 30° to 39° west longitude shown in figure 72, V and VI, and also in the air temperature curves for Eastport, Para (shown in curves VII and VIII) and in part also of the curves for Barbados, Ponta del Gada, St. Helena, Hongkong, as shown in curves IX, XI to XIII, and also in the surface temperature curve for the equatorial field at 29° to 31° west longitude (curve X). The curve for St. Johns (XIV) shows a similarity with that for Eastport, but differs in having a secondary maximum in the year 1904. Considerable similarity with this type is also found for the type which includes El Paso, Corpus Christi, Bombay, Honolulu (XVI to XIX) and similarity with these is again found in the curve for Cape Colony, (XV) but this last type, the Bombay type, runs as we have said directly opposite to the types of Batavia.

To a completely different type belong the curves I and II of figure 73, for the air temperature in the western United States on the coast of the Pacific Ocean. These comprise Mielke's region No. 10 as collected by us, and curves for Los Angeles in California after Arctowski. Some similarity with this type is found in the temperature curves for Havre and Miles City, both in Montana. There is a certain degree of similarity to these in the Greenland curves for Upernavik and Ivigtut (V and VI), but there is a further development from these over to Angmagsalik (VII) and Berufjord (VIII) on the east coast of Iceland and to Thorshaven (X) on the Faroe Islands. An agreement with the last named curve is shown by curve IX for the surface temperature in the eastern Danish field 0° to 9° west longitude south of the Faroe Islands, and this again has a partial agreement with the curve for the air temperature in all Norway (XI). These curves have again a certain similarity with the curve XII for the the air temperature in Bermuda and also with the curve for San Juan in Porto Rico (XIII). This again, as mentioned above, has a similarity with the curve for the surface temperature of the ocean in the Dutch 10° square at 15° to 24° north latitude (XIV) and also with the curve for Arequipa (XV).

If we had curves for stations lying between, of which Arctowski gives some, we should see a gradual transition between these different curves. We see that in this way a correlation between the temperature variations in very widely different regions of the earth may be found, while in closer lying regions between them occur

variations very different and often having almost entirely different characteristics.

Two of the principal types which we may call those of Batavia and Bombay show variations which on the whole in the period of time between 1900 and 1910 were in complete opposition. Several of

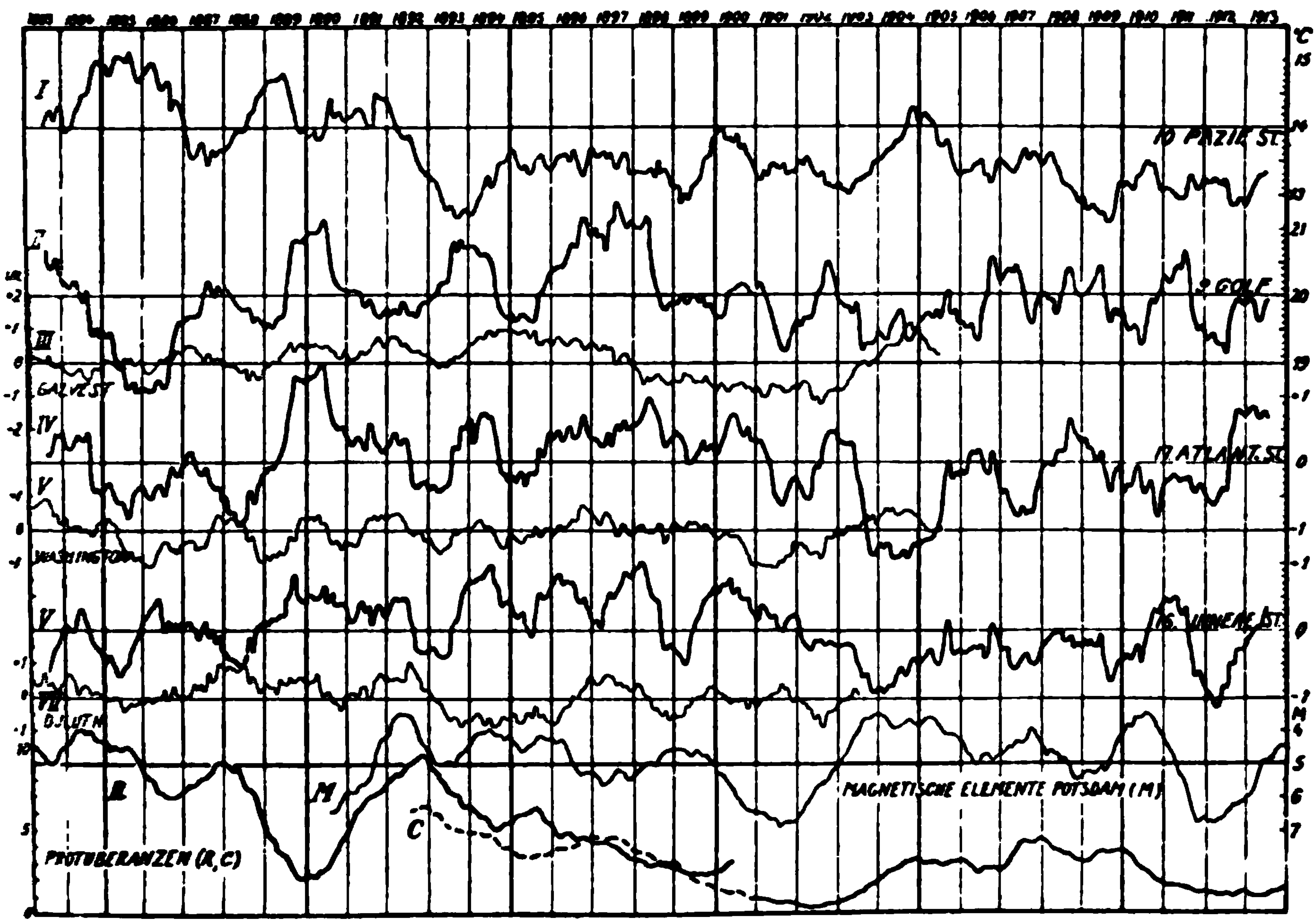


FIGURE 74. Curves with consecutive twelve-month smoothing for the monthly mean temperature in the United States. I: in Mielke's region 10, Pacific States (north, middle and south Pacific Coast). II: Mielke's region 9, Gulf states (Florida, east and west Gulf). IV: in Mielke's region 17, Atlantic states (New England, southern and middle Atlantic states). VI:[1] Mielke's region 16, interior states (lower and upper lake region, Ohio, upper Mississippi-Missouri Valley, northern, middle and southern plateau). Curves III, V, VII: Air pressure in Galveston, Washington and Duluth. M: degree of disturbance of the three magnetic elements in Potsdam.[2] R. and C: monthly means of daily number of prominences according to observations in Rome, (R) Catania (C). All curves indicate the consecutive twelve-month smoothed mean values.

[1] Incorrectly indic ted with *V* in the figure.

[2] The numbers on the scale for *M* should be 6, 5, 4, 3, instead, 4, 5, 6, 7.

the other curves, particularly the type of curves represented by the surface temperature of the middle Atlantic Ocean, the most westerly of the Danish fields (fig. 72, V and VI), Eastport, Para, and St. Johns are transition forms between these two opposite types.

TEMPERATURE VARIATIONS IN THE UNITED STATES

We now go on to consider the curves in figure 74 which give the meteorological relations in different regions of the United States, and we find here in the temperature curves as shown in plate 18-L two types. The one type is represented by the curve for the region on the Pacific coast (curve I) and the other by the curves of the eastern states on the coast of the Alantic Ocean (curve IV) as well as those for the Mexican Gulf (curve II). The temperature curves for the interior states form a transition between these two types of curves and have now the one type, now the other. Where both types simultaneously have minimum or maximum these are particularly strongly marked in the transition forms, as for example the minimum in the years 1898 and 1899. This agrees also completely with what Hildebrandsson has pointed out, when he indicates an action sphere along the Pacific coast and another in the eastern states.

Considering now these curves for the time interval after 1900 we find that the curve for the Pacific is of a very individual type of its own while the other type characteristic of the easterly stations on the Atlantic coast is the same as that represented by Batavia and the other tropical stations which we have investigated, including Arequipa. After 1900 there appears a dissimilarity between the curve for the Gulf states and the curve for the Atlantic states, while these two curves for the time interval before 1900 had complete agreement. This disagreement for the later period of time is of such a nature that the curve for the Gulf states is similar to the curve for Corpus Christi (see fig. 72, XVII) which was indeed to be expected since this lies on the Gulf, but it also is similar to the curve for Bombay and the other similar curves.

If Hildebrandsson is right in his conception of the action spheres, we should expect that the curves for the eastern United States along the coast of the Atlantic Ocean as well as the curve for the Gulf states would have similarity with the temperature curves for Scandinavia. Placing these American curves with the curve of the coast temperature along the Norwegian coast, the curve for the air temperature for all Norway, and the air temperature in Stockholm, we find a remarkable agreement. This is plainly shown in figure 75 without more particularly describing it. This indicates that Hildebrandsson is right in his view. In the same figure at the top we have given the twelve-monthly smoothed curve for Liepe's station No. 1. As the reader will see, this does not

agree completely with the other curves but shows in several time intervals of many years a close agreement. Occasionally, however, it goes oppositely. It forms plainly a mixed form between the two types of curves, in the same way as the curve for the interior states of North America. This is also as we should expect following Hildebrandsson, since this curve should agree with the curve for middle Europe, which is a mixed form between the curves for north Europe and those for south Europe. The south European curve should furthermore, according to Hildebrandsson, agree with the curve for the Pacific coasts.

SUDDEN DISCONTINUITIES IN THE AGREEMENT BETWEEN THE CURVES OF DIFFERENT STATIONS

If we compare the curves of figure 75 for Batavia and the American region, we see that the variations in the Atlantic states and Batavia ran parallel in the period of time after 1897. In the earlier years, however, the two curves go in inverted directions, and the variations at Batavia correspond to the variations on the Pacific coast. As we have already remarked, the variations in Batavia and at Bombay go oppositely to one another in the time interval 1900 to 1909, but not, however, for the time 1880 to 1889 (see fig. 71, VIII-*a* and *b*). Except for the Arctowski curves for the above mentioned time interval we have not had opportunity to study the temperature relations in Bombay by similar twelve-monthly smoothing as we have done for Batavia. In order to make a comparison for the earlier years between the temperature variations in Bombay and in Batavia we have therefore been obliged for the present to restrict ourselves to the yearly means of temperature which are found in Mielke's plates, and from them we have constructed curve IV in figure 91. From this one sees that the two temperature curves III and IV ran oppositely after 1897, but parallel before that time.

The opposition between the types for Batavia and Bombay holds only for the last series of years after 1897 and not for the earlier years. A somewhat similar relation holds as between the curves for Batavia and the Pacific states. It is moreover possible that the same thing occurs for the temperature variations at several other stations where the curves for the last time interval after 1900 follow an opposing course. The conclusion may therefore be drawn that a given station does not always continue within the same climatic region or action center, for the boundaries of it are more or less displaced and often over a long series of years, so that in

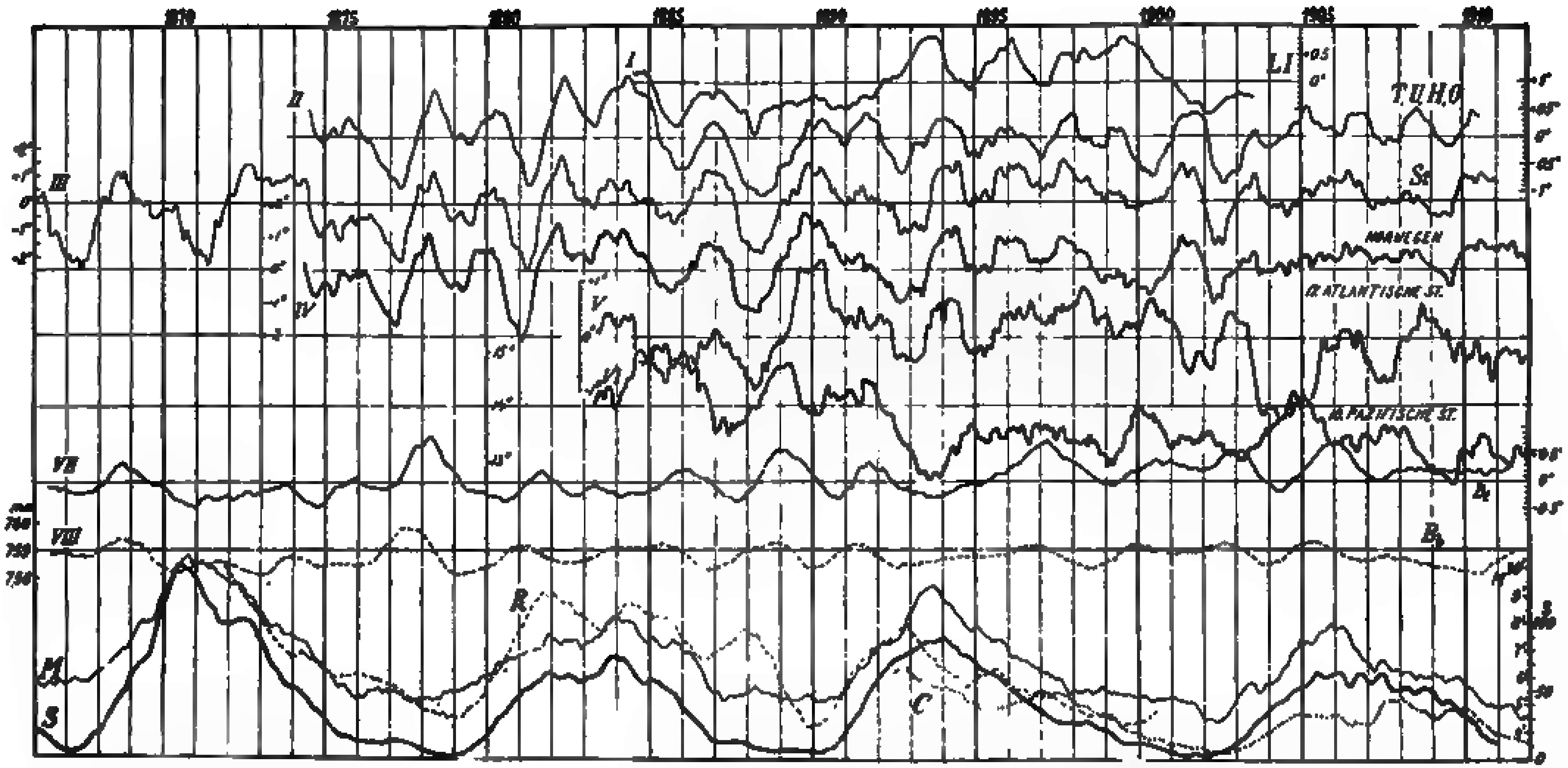


FIGURE 75. Curves fo ; of temperature anomalies by consecutive twelve-month smoothing. I: in Liepe's station I at the surface n nnel. II: at the four Norwegian lighthouses, Torungen, Utsire, Helise and Ona, surface temperatures. II :mperature. IV: all Norway, twenty-two meteorological principal stations. V: in the eastern United States, Atlantic states, Mielke's region 17. VI: The Pacific states, Mielke's region 10. VII: in Batavia. VIII: air pressure in Batavia. M: twelve-month means of the daily declination variation in Christiania. R and C: twelve-month means of the daily numbers of prominences according to observations at Rome (R) and Catania (C). S: smoothed relative sun-spot numbers according to Wolfer. All curves indicate the consecutive twelve-month smoothed mean values

this series of years an inversion of the variations occurs at the given station. This happens, as Hildebrandsson has rightly claimed, at stations which are on the boundary between two action centers, as for example in middle Europe and interior America, but the boundary displacements can obviously at times be so great as to bring in places which at other times have very well-marked type characters.

VARIATIONS IN DIFFERENT METEOROLOGICAL ELEMENTS

Before we go farther in our consideration of the temperature and its variations we will say a few words on the variations in other meteorological elements, as these have come within our investigations and are shown on figure 71.

As for precipitation, we have outside of Batavia the twelve-monthly consecutive means only for Antananarivo on Madagascar and for Fort de France in the West Indies (curves P.). As regards Antananarivo, there are here no well-marked agreements between the variations in the air temperature and the variations in precipitation. The latter seems generally to run oppositely to the variations in the air pressure.[1] In Fort de France there is also no well-marked agreement between the variations in precipitation and the variations in temperature, although on the other hand the curve for the precipitation goes pretty well with the air pressure.

As for the cloudiness we have only the twelve-monthly consecutive means (fig. 71, IV, N) for Antananarivo, except those for Batavia given in figure 68. It appears from these that the cloudiness has a certain tendency to vary oppositely to the temperature. The scale of cloudiness is given in the figure with increasing values downwards. We find, in other words, the same relation that we found for Batavia, but less well marked.

As regards Batavia, we found a complete agreement between the variations in the daily temperature amplitude and the variations in other meteorological elements. A similar investigation with twelve-monthly consecutive means has been made for other tropical stations and the result is given in the curves T-A in figure 71. On the whole there is here no well marked agreement between these curves and the temperature curves. At single stations, Port au Prince and partly at Mauritius there is an agreement with the curve for the air pressure.

We will now consider somewhat more at length the variations in air pressure which are shown in curves in figure 71. As already

[1] Take notice that the curves for precipitation (P) are drawn inverted.

remarked, there is a very good agreement between the variations of air pressure and temperature at Batavia such that the air pressure variations occur somewhat earlier than the variations in temperature. From figure 71 we see that a complete agreement exists between the air pressure variations at Batavia and at Wellington. A similar agreement with Batavia we find on the whole in the air pressure curve for Mauritius, but not so thorough. However, in the latter years after 1902, there is a tendency to march oppositely or with a very great displacement of phase. The air pressure in Antananarivo shows completely the same variations as at Mauritius. For the two last named stations there is in relation to Batavia so great a phase displacement, especially with regard to the air pressure, that the air pressure curves for these stations go generally in opposite direction to the curves for temperature. That the air pressure variations occur some months earlier on Madagascar and Mauritius than at the stations in India and in Java agrees also with Chambers' results earlier mentioned.

We go now to the two stations in West India and find there less well-marked variations in air pressure and a less or even no agreement with the air pressure variations in the four tropical stations of the eastern hemisphere. The air pressure curves for these West Indian stations show also less agreement with the temperature curves for the same stations. Where there is a tendency to correlation it runs in the direction of opposition.

The air pressure variations at three stations on the American continent are given in figure 74. They show slight similarity with our tropical air pressure curves, but on the whole less marked variations. The greatest similarity is shown by the curve for Galveston with the two curves for the West Indies, as was to be expected. It appears also that a certain degree of agreement exists between the air pressure variations in Galveston and in Washington. The air pressure variations in these American stations appear to be most opposite in their course to the temperature variations in the corresponding regions. In the interval from 1888 to 1902, the air pressure curve for Washington shows the same course as the temperature curve for this region on the whole.

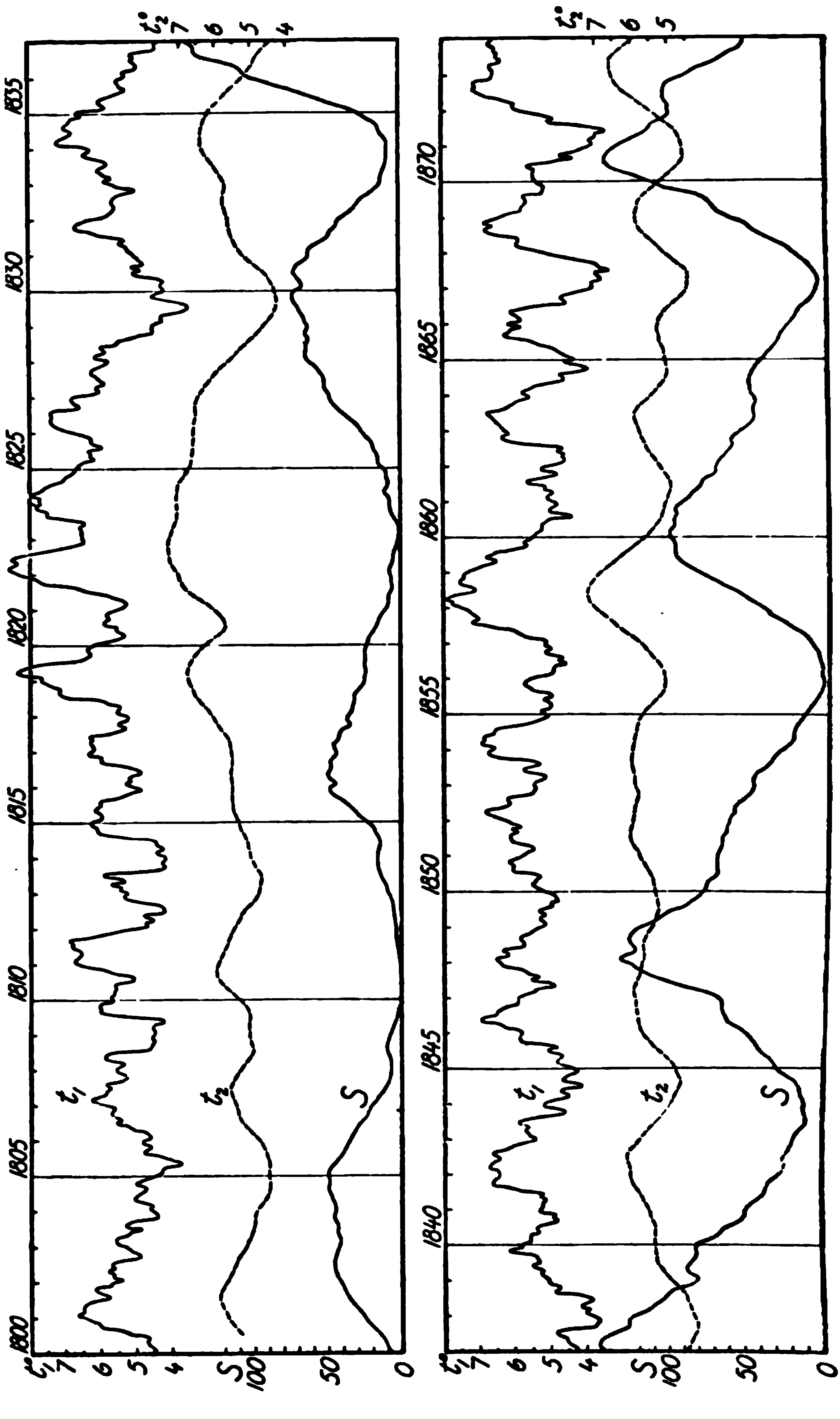
THE AIR TEMPERATURE IN STOCKHOLM

As earlier mentioned Wallén has found several periods of short interval for the variations of air temperature in Stockholm. Of these, one is of about two years or twenty-six months. Also he

finds a longer period of eleven years and one of thirty-three years and even one of a hundred and ten years. The eleven-year period he found divided into two parts with two maxima and two minima.

In figures 76 and 77 we give a comparison of the variations of the air temperature in Stockholm and the sun spot variations. The upper curve designated by t_1 shows the temperature variations as they are exposed by consecutive smoothed means of twelve months. The second curve underneath designated by t_2 shows the temperature variations according to consecutive means of twenty-four months. At the bottom is given the sun spot curve with increasing values downward. In the t_1 curve there appear the biennial variations with a considerable part of their amplitude. Comparing this curve with the smoothed curves in which the two-year period is entirely eliminated one sees that a large number of the short variations have disappeared and in single cases one can see quite distinctly the great strength which the biennial period attained. Such observations may be made for the period from 1810 to 1820 or for that from 1846 to 1856 or concerning the relations of the middle and end of the nineties.

In relation to the longer interval variations we will note particularly the t_2 curves. In several cases one sees well-marked temperature minima in these curves at times when the sun spot minima occurred, as for example 1844, 1855, and 1867. However the sun spot minimum is often long continued; that is to say, the inflection in the curve which comes at the place of minimum is not particularly well-marked and not so sharp as in other cases. In these long-stretched-out minima one finds the temperature minimum not at the lowest point of the curve, but in the transition time of the bending of the curve towards the long minimum. This is, for example, the case in the years 1808, 1820, 1876, 1888, and 1899. The temperature maximum that follows such a temperature minimum is apt to fall while the sun spots are yet few and have hardly departed from the minimum value. In the other cases where the sun spot minimum is more definite and is restricted to a shorter time interval the temperature maximum during the rise of the sun spot numbers occurs between minimum and maximum of sun spots. This relation is conspicuous in the years 1846, 1858, and 1868-69, and besides that in a couple of cases more. Generally near the time of sun spot maximum there is found a new temperature minimum, and this is indeed the case in all of the series of years which we have investigated, that is, from 1800 to 1910. In individual cases it hap-



1800
1805
1810
1815
1820
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
t₁
t₂
S

FIGURE 76.

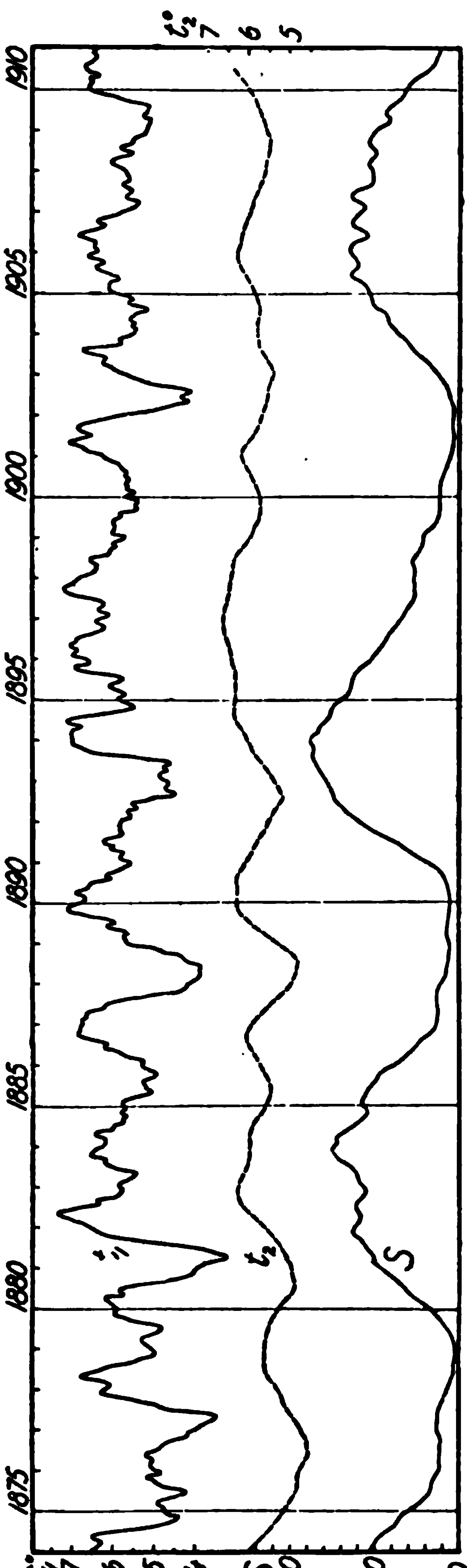


FIGURE 77.

FIGURES 76 and 77. Curves for the air temperature in Stockholm. t_1: values of the consecutive twelve-month smoothing. t_2: after consecutive twelve and twenty-four monthly smoothing. S: curve for the smoothed relative numbers of sun spots according to Wolfer.

pens that the temperature minimum and the sun spot maximum are very near together as in the years 1835, 1837, and 1870. In other cases the temperature minimum falls somewhat after the sun spot maximum, and so it is for example in the years 1860-61; and again in other cases the temperature minimum falls somewhat before the sun spot maximum as in the year 1892. For the air temperature in Stockholm, in other words, a double period occurs during the sun spot period with a temperature minimum near the sun spot maximum and also near the sun spot minimum. We have already repeatedly called attention to a similar division of the sun spot period into two, but in those cases it generally happened that the temperature maximum fell near the sun spot minimum as well as near the sun spot maximum. This was for example the case for the temperature in Russia according to the Mielke-Köppen tables as already mentioned.

VARIATIONS IN THE AIR TEMPERATURE IN STOCKHOLM AND IN THE WATER TEMPERATURE ON THE NORWEGIAN COAST

Before going further we may refer once more to figure 53 which gives the temperature variations in Stockholm and those at the Norwegian lighthouses. We have already said that the short period temperature variations along the Norwegian coast and in Stockholm agree in many particulars. From the *B*-curves of figure 53 it may be seen that the variations of more than a single year interval agree remarkably. From the *C*-curves of the same figure, which represent temperature variations smoothed by taking twenty-four-month consecutive means after a first smoothing by twelve-month consecutive means, it is apparent that the variations which have long periods agree particularly well. In other words not only the short interval temperature variations, but also the variations which have a very long period are common in the water along the Norwegian coast and in the air temperature of Scandinavia. There is on the whole a displacement such that the variations in Stockholm occur somewhat earlier than the corresponding variations on the Norwegian coast; and that applies not only to the earlier mentioned short period variations, but even more to all variations with a long period. Though the variations which are to be recognized in both *C*-curves have the same general trend yet the curves are not fully parallel, but are somewhat displaced, so that in individual cases the distance between the curves is somewhat greater than in other cases. In the years 1875 to 1885 the coast water on the Norwegian coast

was considerably warmer than one would have expected by consideration of the temperature in Stockholm. In the following twenty years the coast water temperature was considerably lower than the temperature in Stockholm would indicate. It is possible that periodic fluctuations of long interval play a part in this, which produce different effects upon the coast water and upon the air temperature. But the variations which occur in periods of not very many years are quite similar. A certain agreement is found between these *C*-curves and the sun spot curves, but the eleven-year period in the *C*-curves shows the tendency to a separation into several (three or four) shorter periods.

XII. THE RELATION BETWEEN METEOROLOGICAL VARIATIONS AND VARIATIONS OF SOLAR ACTIVITY

PERIODS FOUND IN METEOROLOGICAL VARIATIONS

The result of the meteorological investigations which we have thus far discussed shows that sometimes very great agreement exists between stations which are far apart and situated in very different regions of the earth. In these discussions we have treated principally the variations of the curves after these have been smoothed by twelve-month consecutive means. These curves show principally the fluctuations of a few years, but they also indicate the longer eleven-year periods. We obtained in this way a good confirmation of Hildebrand's conception of the meteorological variations in their grouping about different action spheres.

These fluctuations in the meteorological elements which we have studied in different regions of the earth appear to be in a strong degree periodic. Particularly there appears a period of about two or three years in these curves most conspicuously. A corresponding period is found frequently in the curves for sun spots (see later fig. 95) and for prominences as well as in the disturbances of the magnetic elements.

By a proper formation of means for long periods of years we have shown, as also have Köppen and others, that meteorological fluctuations of about eleven years and of about five and a half years occur. In other words, as we have already said, there appear to be periodic variations of the meteorological elements of one-quarter (and perhaps one-third), one-half, and a whole sun spot period widely distributed over the earth. One cannot resist the conclusion that these periods which have so close a relation to solar activity have great influence on the condition of the earth's atmosphere.

THE AIR PRESSURE VARIATIONS AND THE VARIATIONS IN SOLAR ACTIVITY. CONFUTATION OF EARLIER AUTHORS

As remarked above, an apparent contradiction exists among the results of earlier investigators with reference to the periodicity of air pressure variations in different regions of the earth. On the one hand, Chambers, Broun, Hill, Blanford and others found that the air pressure variations, for example in the Indo-Malayan region, have an eleven-year period during which the air pressure varies oppositely to the sun spots, while the variations occur in the same sense as sun spots in west Siberia, in Russia, etc. On the other hand both Lockyers found a three year or 3.7 year period in the air pressure variations in Bombay and the Indo-Malayan region in which the air pressure varies directly with the prominences. In other words the air pressure variations appear to go in these short periods directly as the variations of solar activity and opposite to the course which they follow in the longer period of eleven years.

Examining this matter more closely, we find, as remarked above, that the curves published by the two Lockyers (1902, p. 501) show not so complete an agreement between the variations of the prominences and the air pressure variations as one would have expected from their publication. In the period from 1880 to 1890, which the two Lockyers investigated, the observations of the Osservatorio del Collegio Romano show three very well-marked periods in the prominences in the run of the eleven-year sun spot period, and in the same time interval there appear air pressure variations in Bombay with corresponding periods. But in the time after 1890 the Lockyers' own curves show that the air pressure in Bombay varied oppositely to the prominences. This appears also in our figure 71, where curve VIII-B indicates the air pressure variations in Bombay and the curves R and T-C show the variations in the prominences. The curves R are according to the observations of the Osservatoria del Collegio Romano and P-C the observations in Palermo and Catania (see pl. 20-S).[1] While the Roman promi-

[1] In "Memorie della Societa degli Spettroscopisti Italiani" the Italian astronomers Tacchini, Ricco, and in part also Mascari, have given papers on the observations of the solar prominences in the observatories of Rome, Palermo and Catania for the years from 1871 till the present. But the observations extend over unequal numbers of years for the different observatories. In Rome the publications extend from the year 1871 to 1900; for Palermo, from 1878 to 1893; and for Catania for all years since 1892. According to these reports we have prepared an illustration of the number of observed prominences per observation day for each month and for each observatory. It

nence curve shows maxima in the years 1884 and 1887-88, which agree with the corresponding maxima in the air pressure curve in Bombay, the two prominence curves show a maximum in the year 1892 that falls with the minimum of the air pressure in Bombay.

The Sicilian prominence curve shows also a secondary maximum in the year 1897 that agrees with the minimum in the air pressure in Bombay. On the other hand it shows the maximum of prominences in the years 1904 and 1905 that falls with the maximum of air pressure in Bombay. It is true that the two curves for prominences do not fully agree. This is partially due to individual peculiarities in the observations. At all events there are long periods of time when the prominence curves have very slight variations, while there are great variations in the corresponding meteorological variations on the earth.

For the sun spots, as we know, the earlier investigations showed no well-marked periods of several months or of a few years such as the prominences indicate. However, as we shall show later, more careful analysis brings to light such periods. It is possible that the solar faculae or the calcium flocculi would give a better expression of these shorter periods in the variations of solar activity, but we have not had opportunity to investigate this carefully. On the other hand, it is a well known fact that the variations in the magnetic forces on the earth have a very close relation to the variations in the

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appears from this that a considerable difference exists between the observations at the different observatories, such that, for example, the observations in Rome on the whole show a considerably greater number of prominences per day than the observations of Palermo and Catania, and they give also more marked variations in the periods of few years as may be seen in the curves, for example, figure 68, curve R.

The values for the observed number of prominences per observational day we have plotted in consecutive twelve-month means in the common way and the values so found we have given in our curves; for example, figure 68, where the curve R represents the number of prominences for the observations of the Roman Observatory, curve P for the observations in Palermo, and the curve C for the observations in Catania. In figures 71, 74 and 75 we have repeated these curves, R for the observations in Rome, P-C for the observations in Palermo and Catania combined, and curve C for the observations in Catania exclusively.

Bigelow in 1908 has also given a list of prominences for each month for the years 1872 to 1905, but this curve we could not use since the numbers of prominences it showed were those of the whole months without reference to the number of observational days, so that the months with few days had few prominences even though the number of prominences at a time was large.

solar activity, and it is possible that they may be used advantageously as a measure of it.

In the curve M of figure 71 we have given the variations in the degree of disturbance (measured as the number of unquiet hours) of the three magnetic elements, the declination, horizontal-intensity and vertical-intensity at Potsdam. The degree of disturbance of the elements is reduced to characteristic numbers according to Eschenhagen's system. The scale is given on the right. The reader will see that the curve shows maxima in the years 1892, 1894, 1903 and 1904, and 1907, when the curve for the air pressure in Bombay shows minima, while in the years 1890-91, 1893, 1895, and 1901, the disturbance of the magnetic elements was small when the air pressure in Bombay had either maxima or was relatively high. In the years 1897 and 1898-99, on the other hand, both curves showed simultaneously minimum or maximum. We see from this that the agreement between the two curves is not complete whether one takes them direct or inverted.

Going on from this to compare the curve for the prominences and the magnetic elements at Potsdam, with the air pressure curves in the other stations in the Indo-Malayan region given on figure 71, namely Batavia, Wellington, Mauritius, Antananarivo, we find the same result—that the relations are sometimes direct, sometimes inverse. For example the maximum of prominences in the years 1884 and 1885 was found simultaneously with the maximum of air pressure in Batavia and Wellington; and also the minimum of prominences in the years 1889-90 finds a corresponding minimum of air pressure in Batavia, Wellington, Mauritius, and Antananarivo. On the other hand, the maximum of prominences in the magnetic curves for 1892 corresponds with the minimum of the four air pressure curves. Therefore there is a variable relation, as already found, for the air pressure curve for Bombay.

If we take now the air pressure variations after 1900 for Batavia and compare them with the magnetic curve for Potsdam we see that while, for example, the minimum of the magnetic curve for 1901 corresponds with a small secondary minimum in the air pressure curve for Batavia, yet the maximum of the magnetic curve for 1903 and 1904 corresponds with the minimum in the air pressure curve for Batavia. On the other hand, in the time about 1905-8, the two curves run approximately parallel. In the year 1910, again the maximum of the magnetic curve corresponds to the minimum of the air pressure curve of Batavia, while in the year 1911 these two

curves also run in opposite directions. A comparison of the prominence curve and the air pressure of Batavia for the same interval of time gives about the same results except that the prominence curve shows no maximum in the years 1903-4 corresponding to the minimum of air pressure. The maximum of the magnetic curve in the year 1910 corresponds to a maximum three-quarters of the year earlier in the prominence curve.

In consequence of the above mentioned phase displacement of several months in the air pressure curves of the four stations of the Indo-Malayan region in relation to one another, there is some difference between the agreement or lack of agreement of these curves with the magnetic curve or the prominence curve, but on the whole they show in spite of it the same relations.

Consequently we see that, as regards the periods of a few years, there is no certain agreement between the air pressure variations and the variations in prominences as was announced by the two Lockyers. At certain isolated times, as we have seen, the air pressure goes directly with the prominences and at other times oppositely to them. The same thing is found if we compare the air pressure variations with the variations in the disturbance of the magnetic elements as observed in Potsdam. Considering Batavia and the Indo-Malayan region it appears as if in general they go oppositely to one another.

As for the air pressure variations at the two other tropical stations given in figure 71, namely, Port au Prince and Fort de France, there cannot be found here either any fixed rule for agreement between the air pressure variations and the variations in the prominences and the magnetic elements. In the most cases it appears that the air pressure in these stations goes directly with the prominences and magnetic elements, but with some displacement of phase. This shows particularly well in a comparison between the curve for air pressure at Fort de France (fig. 71, VI, B) and the curve for the disturbance of the magnetic elements at Potsdam (M).

THE RELATION BETWEEN TEMPERATURE VARIATIONS AND VARIATIONS IN SOLAR ACTIVITY

Examining now the variations in the temperature at these tropical stations more closely we find that in consequence of the earlier mentioned displacement in the air pressure variations in relation to those of temperature, the latter behave somewhat differently with regard to the variations in the prominences and magnetic elements.

But here we find the same relation, namely: the temperature sometimes goes directly with the curves of solar radiation and sometimes oppositely to them. This is perhaps even more marked for the temperature than for the pressure variation. Take for example the temperature curve for Antananarivo (fig. 71, IV, T). It shows for the time 1887 to 1896 a remarkably direct agreement with the curves for prominences and magnetic elements in Potsdam, but for the years 1897 to 1904 the temperature curve for Antananarivo runs oppositely, particularly to the magnetic curve. Then after 1905 the curves go together for some years until again in 1910 and 1911 they run oppositely, and so it is with the other curves. In figure 68, one can compare the curves of different meteorological elements of Batavia for the series of years 1860 to 1909 with the curves of sun spots and prominences, which are the lowest in the figure. We find here the same thing. While the *c*-curves (which are obtained by consecutive twenty-four-month means) show agreement with the inverted sun spot curves, so that the most distinctly well-marked maxima of temperature and air pressure fall upon the minima of sun spots, the short variations of a few years shown in the *b*-curves (which are prepared from consecutive twelve-month means) go partly directly, partly oppositely with the variations of a few years in the prominences.

In figure 74, at the bottom, we have given the prominences, and the curve M for the disturbance of the three magnetic elements in Potsdam. We see that a great similarity appears between the last mentioned curve and the topmost temperature curve for the Pacific coast of the United States. The temperature varies directly with the variations of the magnetic elements. But maximum and minimum in the magnetic curve fall before maximum and minimum in the temperature curve. On the other hand, the variations of the three other temperature curves for the United States go on the whole generally oppositely to the variations in the prominences and in the disturbance of the magnetic elements.

In figure 75, at the bottom, we have the curves of sun spots (S) prominences (R, C) and the daily variation in the magnetic declination in Christiania (M). It appears that the variations of a few years' period in the temperature of the water for the coast stations of Norway, the air temperature in all Norway, and the air temperature in Stockholm (II-IV) go partly direct with the variations of a few years in the curve of declination in Christiania; but that the variations in the latter occur somewhat before the variations in the temperature (see for example the waves in the magnetic curve for

1881-2, 1883, 1884, 1885-86, 1893-94, 1901, 1903, 1905-6, 1909-10). But there are glaring exceptions, as, for example, minimum in the Stockholm temperature of 1871, and maximum in all three temperature curves in the year 1878, the strong minimum in the year 1881, the maximum 1889 to 1890, etc. In a number of these years there appear in the three Scandinavian curves complete agreement with the American curve V for the Atlantic region of the United States, but after 1898 the curves as we have already said go oppositely to one another. For the last named interval of time, it appears as we have said that the Scandinavian curves have more similarity with the other American curve VI for the Pacific coast, while these curves go oppositely to the Scandinavian curves before 1894.

As already remarked, Bigelow maintains that the temperature on the Pacific coast goes oppositely to the prominences in the eleven-year period, but directly with them for the short interval periods of about three years. This does not appear to be altogether correct. To be sure the temperature of the Pacific region, see curve VI, in the two eleven-year periods between 1878 and 1900, which Bigelow particularly investigated, goes oppositely to the prominences and the sun spots. But after 1900 the temperature varies directly with them, which is also shown in part by the careful study of Bigelow's own curves, which, however, stop with the year 1905. In our curves, figures 74 and 75, this is better shown. The maximum in the year 1905 in the temperature curve for the Pacific region falls with the sun spot maximum in the same year, while the minimum some years earlier falls with the minimum of the sun spot and prominence curves. In the years 1910 and 1911 the temperature on the Pacific coast was relatively low, when we had sun spot minima and prominence minima. In the periods of few years the variations of temperature go partly directly with the prominences and the disturbances in the magnetic elements, but at other times oppositely to them in the Pacific states.

In the middle United States and in the most easterly states, Bigelow is of the opinion, as we have said above, that in the eleven-year period, as in the period of three years, the temperature goes oppositely and the air pressure directly as the prominences and the disturbances in the magnetic elements. This is, as we have seen, partly correct, but there are many exceptions when the variations go oppositely to those which Bigelow would predict, and these are apparent from his own curves as well.

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THE TEMPERATURE VARIATIONS IN DIFFERENT MONTHS OF THE YEAR IN BATAVIA

We have already shown that earlier investigators found a difference between summer and winter as to the eleven-year periodical variations of the meteorological elements. For example, Blanford's curves for air pressure in Siberia and Russia indicate that these go directly with the sun spots during winter and oppositely to the air pressure variations in India, while in summer they agree with the latter and go oppositely with the sun spots. The two Lockyers found also for different stations that the air pressure goes differently in relation to the prominences in summer and winter.

It would be therefore of great interest to study the eleven-year variations in the meteorological elements for each month of the year at different stations. Figure 78 gives curves of variations of the temperature (t) and the air pressure (P) in Batavia for each month of the year (curves I to XII). They are smoothed first by consecutive two-year and then three-year means, that is to say, according to the formula $t=\frac{1}{6}(a+2b+2c+d)$. The curves A indicate the corresponding values for temperature and air pressure for the whole year and the lowest curve S is the curve of relative sun spot numbers. It may be seen that in all these curves there is a great similarity, and that the variations on the whole for all the months go in the same direction, and show agreement with the inverted sun spot curve, although with some irregularities. The variations are generally more marked in the winter months and least marked in the summer months (VI to VIII). The air pressure curves run on the whole in pretty good agreement with the curves for the temperature, but as earlier mentioned with a displacement of phase; that is to say, the variations of the air pressure come earlier than the variations of temperature. At special times there occurred great differences, so that the air pressure curve may even go oppositely to the temperature curve, as for example in December and January and partly also February for the years 1883 to 1886, for February and March, 1895 to 1906, and at other times, but a fixed rule can hardly be laid down in this respect. It appears for example, that the air pressure in December has a tendency to go oppositely to the temperature variations, but the result for the year in spite of this is as curve A shows a quite good agreement between variations in air pressure and variations in temperature, and these curves show further, as already said, a quite good agreement with the sun spot curve.

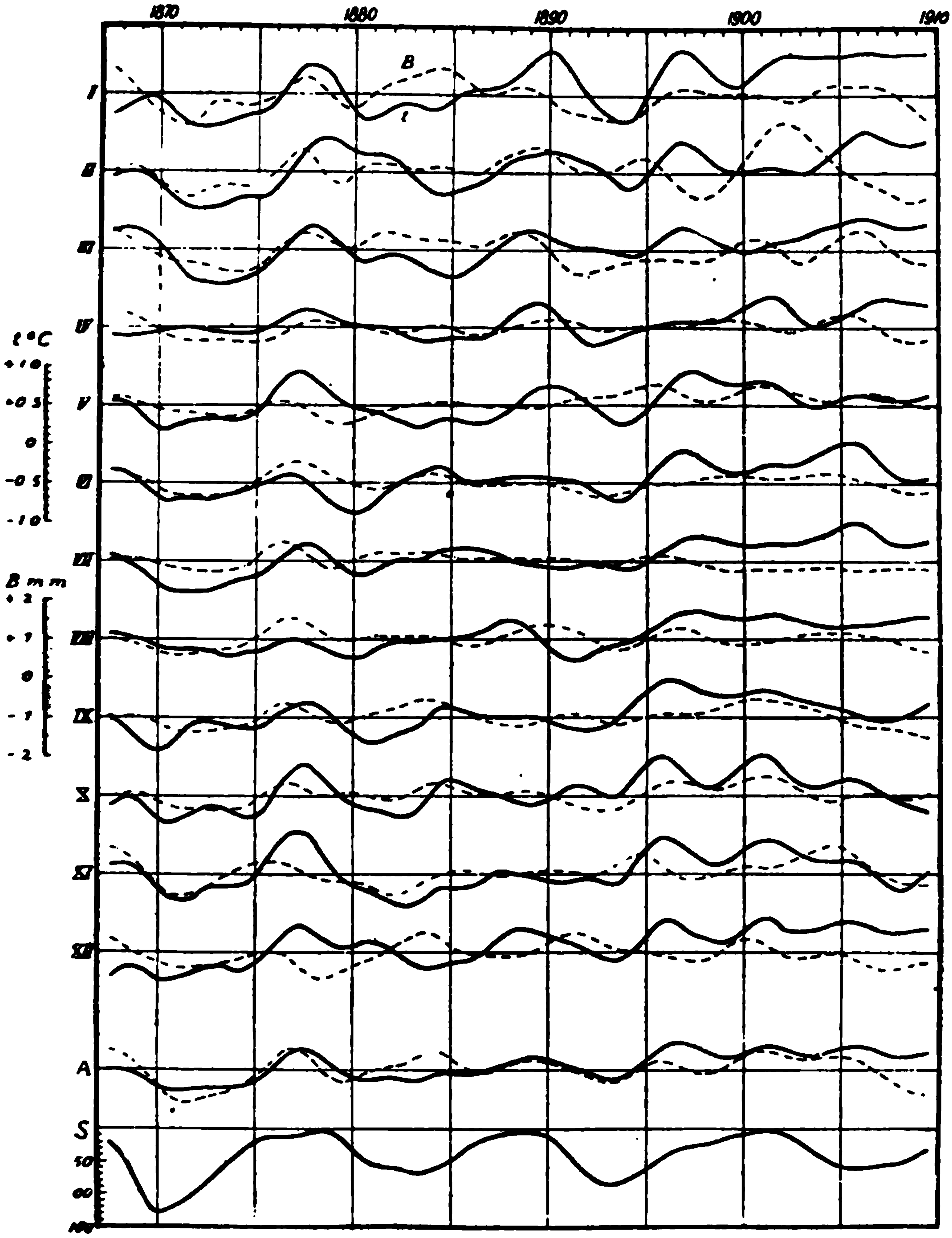

FIGURE 78. Anomalies of the air temperature (t) and of the air pressure (B) in Batavia for each month of the year (I to XII) for the whole year (A) in combined two- and three-year smoothing. S: relative sun spot numbers.

It may be seen that all these curves have a tendency to show a division of the eleven-year period into two or three parts, and this in spite of the two-year and three-year consecutive smoothings.

THE TEMPERATURE VARIATIONS IN DIFFERENT MONTHS OF THE YEAR IN FORT DE FRANCE

In figure 79 we give for the different months of the year (I to XII) as well as for the whole year (A) curves for temperature (*t*) and air pressure (B) at Fort de France which are smoothed in the same way as the curves of the previous figure. The temperature curves show, as the reader will see, a very good agreeement for all months as well as for the whole year with the inverted sun spot curve S which is at the bottom of the figure; but in almost all months, particularly in the autumn, the winter and spring months, and least in the months of July, August, and November, there is a marked tendency to a two-fold division of the eleven-year sun spot period. A tendency to such division into two is even shown in the sun spot curve itself, but it comes much plainer to expression in the inverted consecutive three years mean smoothed curve for the disturbance of the three magnetic elements in Potsdam (M).

The curves for the air pressure in Fort de France show less simultaneous agreement for the different months. On the whole they go for the most part inverted to the temperature curves, and therefore directly to the sun spot curve, and this is also indicated in the air pressure curve for the whole year, curve A. The minimum for the air pressure curve falls here in about the middle between maximum and minimum of sun spots. The tendency of the air pressure to inverted course with respect to the temperature is most marked in the summer months, and especially in June to August; while in the winter months from November to February or March the variations of air pressure have almost the same course as the temperature variations. Also in the air pressure curves there is shown a tendency to a secondary division of the eleven-year sun spot period.

THE TEMPERATURE VARIATIONS IN DIFFERENT MONTHS OF THE YEAR IN STOCKHOLM

As an exam[illegible] variations in different months in hi[illegible] he temperature curves for [illegible] XII) and for the whole

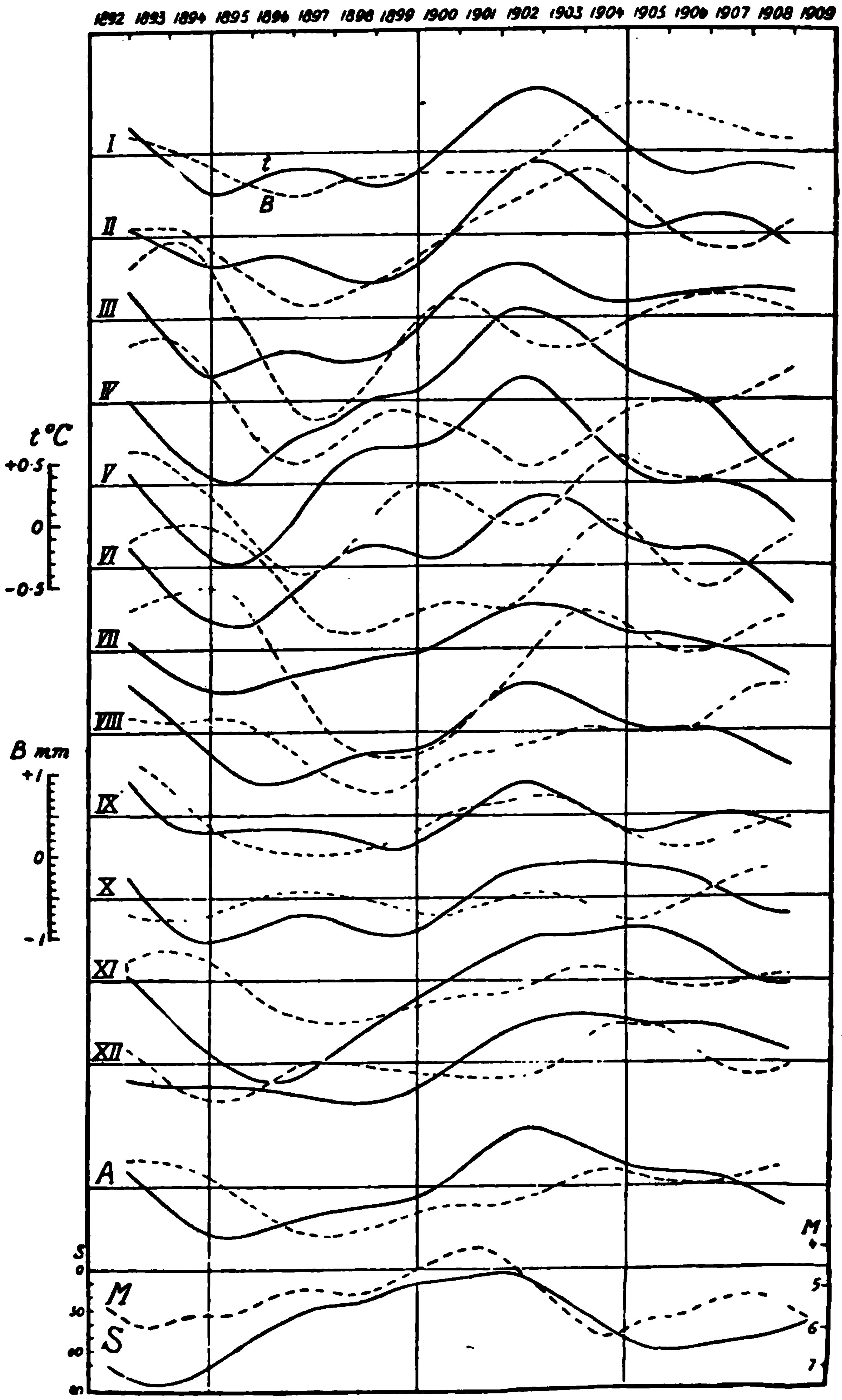

FIGURE 79. Anomalies of the air temperature (t) and the pressure (B) at Fort de France for each month (I to XII) and for the whole year (A) by combined two- and three-year smoothing. M: degree of disturbance of the three magnetic elements in Potsdam in consecutive three-year smoothing (Scale on the right). S: relative sun spot numbers, scale on the left.

year (A). The temperature values have been subjected to a combined two- and three-years' smoothing. At the top is the curve S for the smoothed mean of the sun spot relative numbers according to Wolfer. The curves show a considerable difference in temperature variations between summer and winter. The variations are greatest in the winter months, December, January, and February, and go then in great measure (particularly in January) oppositely to the variations of the sun spots. At certain times, as for example, between 1841 and 1853, curves for February and March run almost oppositely to the curve for January and directly with the curve for

FIGURE 80. Anomalies of the air temperature in Stockholm for each month (I to XII) and for the whole year (A) in combined two- and three-year smoothing. S: relative numbers of the sun spots (scale on the right).

sun spots, and this occurs also in part for the curves for April, May, June, and July. In the years of the interval 1864 to about 1875 the curve for January and also in a slight degree the curve for December goes partly directly with the sun spot curve, while on the other hand the curve for February runs oppositely. In most years, after 1841, the curve for March runs directly with the sun spot curve. After 1885, the curve for April goes directly with the sun spot curve.[1] Most curves show a tenedency to the already mentioned double division of the eleven-year period.

[1] Krogness, as stated above, has found the same for the temperature in Norway in the later periods, namely, that in January it goes oppositely to the magnetic storminess in Christiania and in March–April and also in part in July it goes directly with it.

We see here also, what we have hitherto often found, that no general rule can be laid down. Some parts of the curve go with the sun spot curve and others oppositely to it. It is the curves for the winter months which lend to the curve of the year its distinctive character. We see that until about 1853 this curve went generally oppositely to the sun spot curve, but after this time it went at least as much directly with the sun spot curve.

In figure 81 we give values obtained in the same way by combined two-year and three-year consecutively smoothed means for Stock-

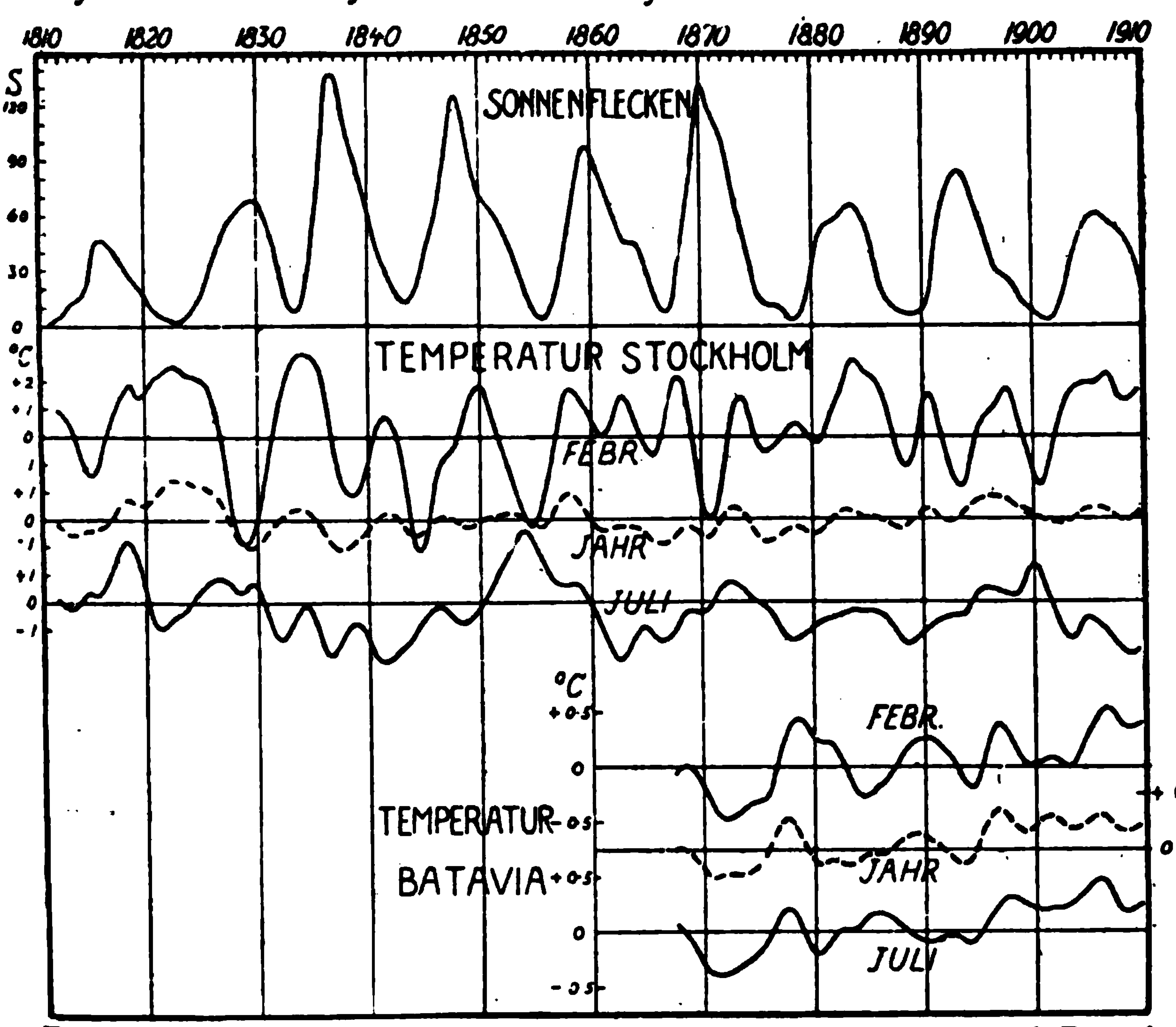

FIGURE 81. Anomalies of the air temperature in Stockholm and Batavia for February, July, and for the whole year in combined two- and three-year smoothing.

holm for February, for July, and for the whole year, in comparison with the sun spot curve. It is clearly shown here that the curve for July goes to a great degree opposite to the curve for February, while this latter in general goes inverted to the sun spot curve, but partly also directly with it. The curve for February has the greatest similarity to the yearly curve.

In the same figure we give also curves obtained in the same way by smoothing the temperature at Batavia for February, July, and

the whole year. It is interesting to see that these curves are partly similar to the curves for Stockholm and partly opposite to them. The February curves show for the time after 1890 quite good agreement. On the whole the two monthly curves for Batavia agree with one another a good deal better than the corresponding curves for Stockholm.

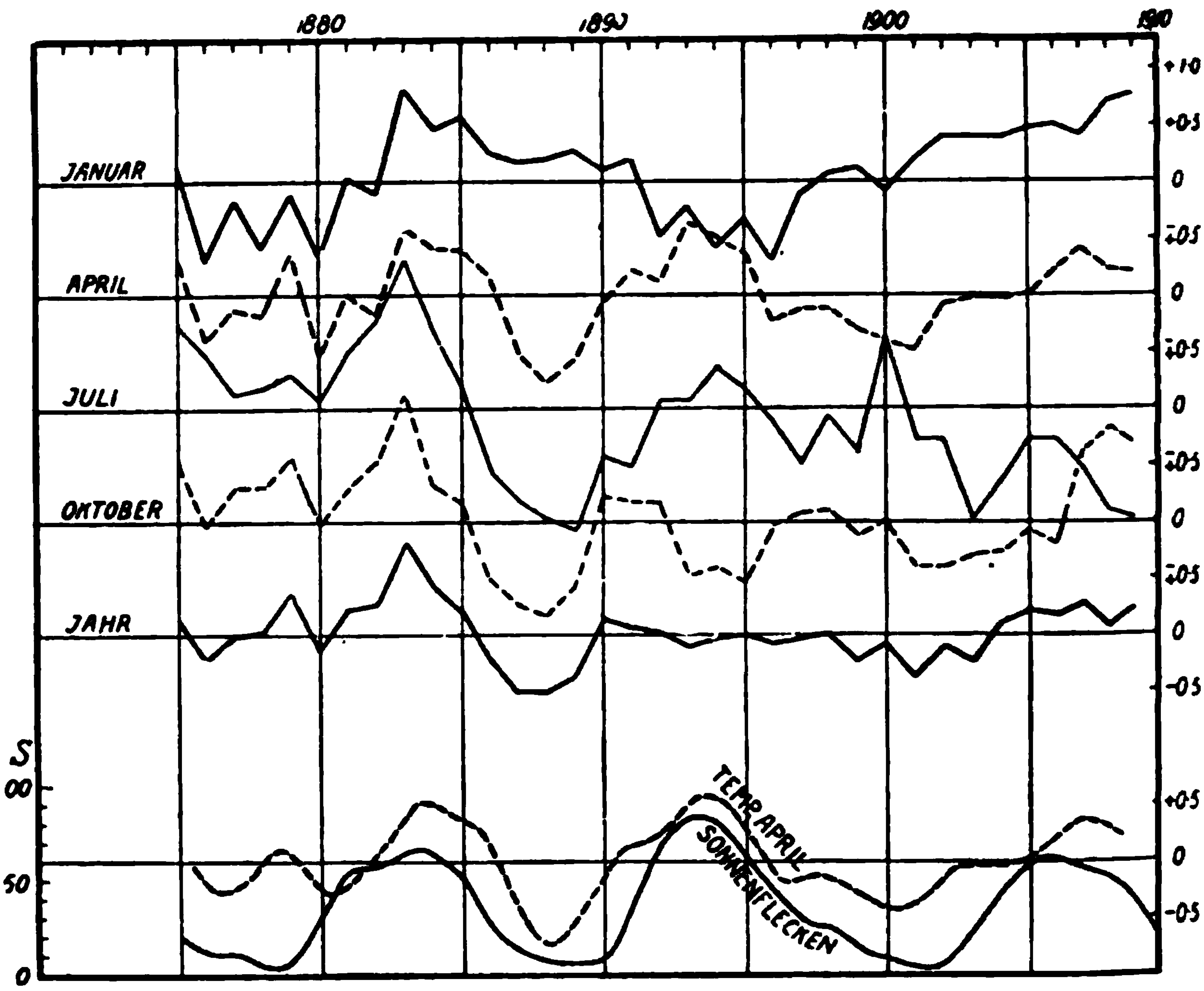

FIGURE 82. Anomalies of the surface temperature at the Norwegian lighthouses, Torrungen, Utsire, Heliso, and Ona for January, April, July, October, and the year in consecutive three-year smoothing and for April (the lowest curve) in combined two- and three-year smoothing.

THE TEMPERATURE VARIATIONS IN THE DIFFERENT SEASONS IN THE COAST WATER OF NORWAY

In figure 82 we give the three-yearly consecutively smoothed temperature curves for the four lighthouse stations, Torungen, Utsire, Heliso, and Ona on the Norwegian coast for January, April, July, and October, and for the whole year. At the bottom of the figure we give the sun spot curve with increasing scale numbers upwards and the temperature curve for April for the four stations after combining by two-year and three-year smoothing. We see that the curves for four months and the whole year are in good agreement up to the year 1890. But after this time the curves for

January and for October go in opposite direction to the curves for April and July, and in a similar way behave also the curves with reference to the sun spot curve. They run in the same direction up to about the year 1890, but after this time the curves for October and January generally go opposite to those of the sun spots. The curve for July shows, however, a disagreement in its high maximum in the year 1900. The combined two- and three-yearly smoothed curve for April shows as the reader will see great agreement with the sun spot curve.

THE TEMPERATURE VARIATIONS IN DIFFERENT MONTHS OF THE YEAR IN THE INTERIOR OF ASIA

It would obviously be of great interest to observe the variations of temperature in different months of the year in the interior of the Eurasian continent, where such extreme conditions with highly developed air pressure maximum in winter and great air pressure minimum in summer prevail. In order to save time we have in this investigation confined ourselves preliminarily to the series of temperature anomalies given by Abbot and Fowle, which they call values for northern Asia. For each month of the year in the time interval from 1876 to 1903, the temperature values published are the average anomalies for the following seven stations: Barnaul, Irgis, Irkutstk, Kisil-Avat, Nertschinsk, Peking and Taschkent.

Unfortunately these meteorological stations are not ideally chosen for our purpose since they lie in different action spheres. One must assume that stations like Peking would have very different variations from stations like Taschkent and Barnaul, since they lie respectively on the eastward and westward sides of the action center with high pressure in winter and low pressure in summer. Lacking better observational material, we may, however, draw preliminary conclusions from the run of the temperatures in the interior of this great continent.

In figure 83 we give the curves for the temperature variations for each month at these stations (I to XII) smoothed to the formula $b=\frac{1}{4}(a+2b+c)$ for the time from 1876 to 1903. Furthermore, we give the curve W for the temperature variations for the three winter months, December, January, and February, and the curve SO for the temperature variations for the summer months, June, July, and August, as well as the curve J for the entire year.

As we should expect, the curves give very great difference in the temperature variations in the different months. Particularly is the

difference remarkable between the winter months and the summer months, when the variations run on the whole oppositely to one another. On these grounds the curve for the entire year (J) shows relatively small fluctuations, since the variations in the different parts of the year go in opposition. But it is remarkable that even within the winter months the variations do not simultaneously agree.

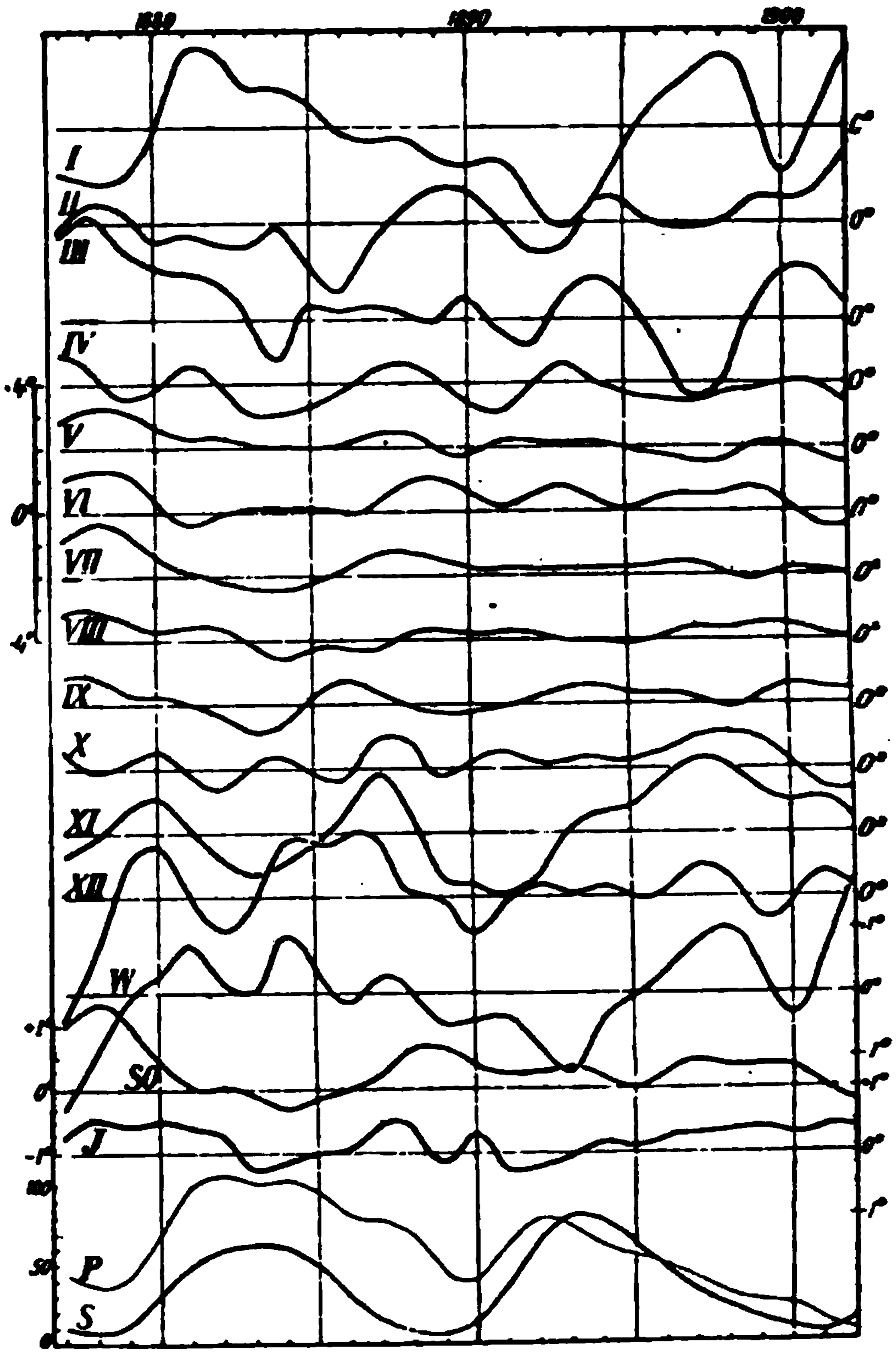

FIGURE 83. Anomalies of the air temperature in the interior of Asia for each month of the year (I to XII), for the three winter months (W), for the three summer months (SO), and for the whole year (J). P: prominences according to the observations in Rome and Catania. S: sun spots. All the curves are smoothed according to the formula $b = \frac{1}{4}(a + 2b + c)$.

For example, the variations in February and partially also those in March tend to go oppositely to the variations in January and also in December and partly even in November.

Taking now these temperature curves for different months together with the curve for the prominences and sun spots (curves P and S at the bottom of the figure), we find that in the first sun spot

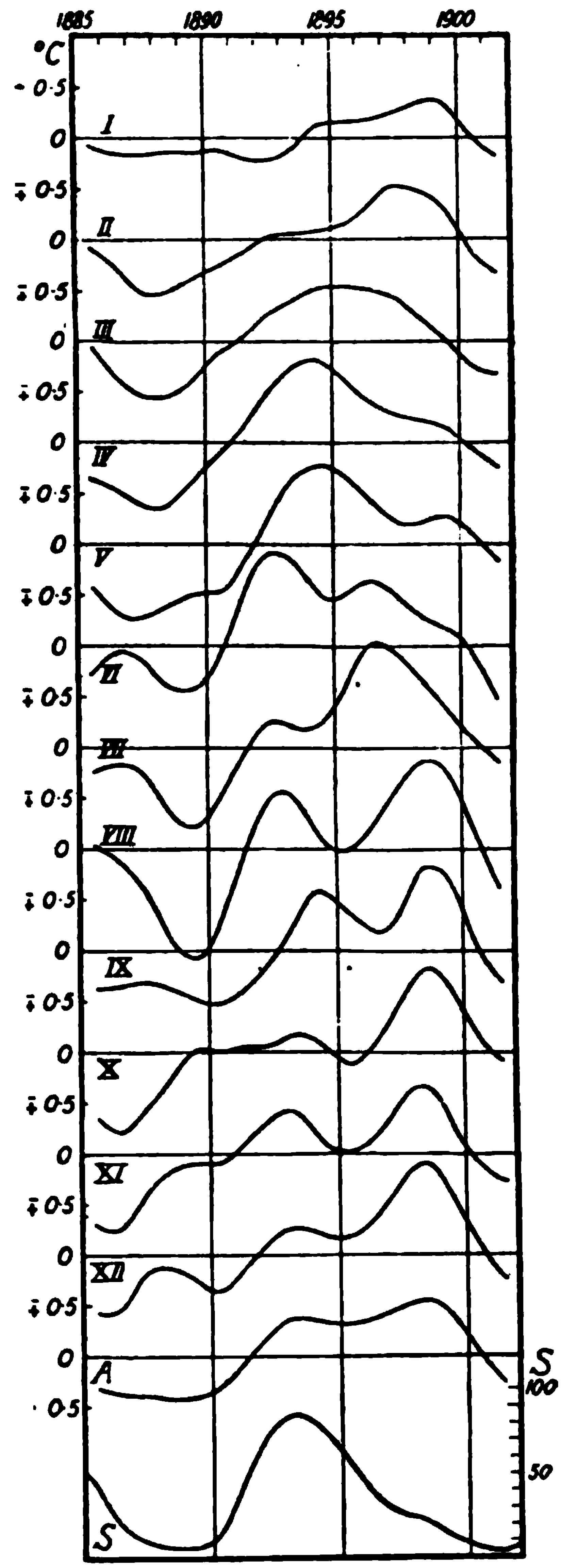

FIGURE 84. Anomalies of the surface temperatures at Liepe's station I (47° north 6° west) for each month (I to XII) and for the whole year (A) in combined two- and three-year smoothing. S: sun spots.

period from 1878 to 1889 the temperature variations in the months December and January (see also the winter curve W) goes directly with the curve for the sun spots and the prominences. In the curves for December and January (probably in February, and see also the curve for October) we find even the three shorter periods in the prominence curve with small maxima in the years 1881 to 1882, 1884, and 1887. In the same sun spot period, 1878 to 1889, the run of the temperature curves for the summer months goes approximately inverted to the sun spot curve and the prominence curve. For the next sun spot period, 1889 to 1901, on the other hand, the agreement between the temperature curves and the sun spot and prominence curves is much less regular. The curve for the winter months shows a minimum corresponding to the maximum of sun spots and prominences in the year 1893 and the curves for November, December, and January have furthermore a remarkable maximum in the years 1897 to 1898 that is particularly well marked in the January curve and that has nothing corresponding to it in the prominences and sun spot curves. The temperature curve SO for the three summer months runs generally reverse to the sun spot curve and the prominence curve. It is very noticeable that this summer curve is much more similar to the yearly curve than the winter curve W is. The cause of this is that the temperatures in March–April and November with their great variations are for the most part inverted to the winter temperature.

THE TEMPERATURE VARIATIONS IN DIFFERENT MONTHS OF THE YEAR AT LIEPE'S STATION ONE

In figure 84 we give the curves for each month of the anomalies of the surface temperature after combining by two- and three-years smoothing of Liepe's station I. We see that the variations in the surface temperature in this most easterly part of the Atlantic Ocean run almost exactly in the same direction in the different months of the year. Besides, we have a great similarity with the variations of the sun spots, particularly in the spring months up to June, when the temperature minimum, as the reader will see, goes almost exactly coincident with the minimum of the sun spots, while the maximum is in part one or two years after the sun spot maximum. In the other months the temperature minimum also falls with the sun spot minimum fairly well, while the temperature maximum in part is several years after the maximum of spots. Particularly in the months, June to November, there is such a strongly marked tendency to a divi-

sion into two of the eleven-year sun spot period, that the latter of the two maxima is gradually, in the run of the months, developed into a principal maximum, and falls several years later than the maximum of sun spots, while the first maximum is in these months about coincident with the sun spot maximum.

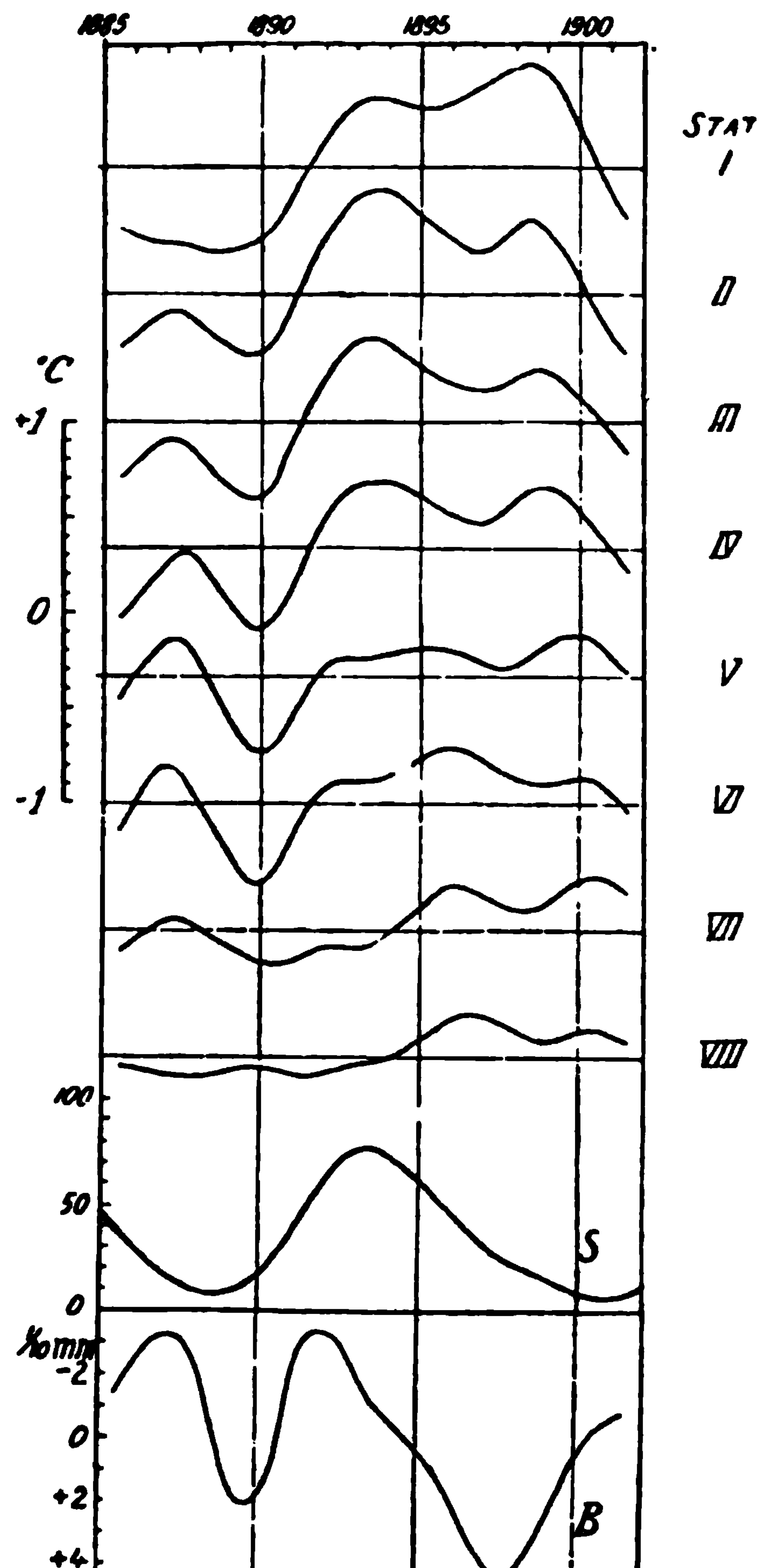

FIGURE 85. Yearly anomalies of the surface temperature at Liepe's stations I to VIII in combined two-and three-year smoothing. S: sun spots two- and three-year smoothing. P: anomalies of the air-pressure differences between 30° north 30° west and Sao Thiago in combined two- and three-year smoothing.

HALVING OF THE ELEVEN-YEAR PERIOD AT LIEPE'S STATIONS

We see here also a similar halving of the eleven-year sun spot period such as we found in the surface temperature of the North Atlantic Ocean and at different meteorological stations (see figs. 69,

78, 79, and others). This halving has been noted by many others, both for temperature and for the precipitation (see Hellmann, Johansson and others as above mentioned). It is exactly this halving of the eleven-year period which Wallén noted so distinctly in the water level of the great Swedish lakes.

It would be interesting to investigate how the other stations of Liepe behave in regard to this, since they extend over a great region from north of the Azores maximum far toward the south. We have obtained by combining two- and three-years' smoothing the yearly means for all stations of Liepe, and we give them in the curves of figure 85 together with the sun spot curve which is smoothed in the same way. The figure shows a remarkable development southwards accompanied by a moderating of the extremes. In the first four stations the variations are strongly marked, while for the southern stations V to VIII they are small, and for the most extreme southerly station VIII they are almost zero. This appears to be quite simply explained by the air pressure distribution, which we shall later discuss. The halving of the eleven-year period is most strongly marked for the more northern stations and southerly to station IV. At stations V and VI there is a division into three, which is partially traceable in the most southerly stations.

In order to get another picture of the development at the series of stations, we have taken, in figure 86, the values for the strongest maximum and minimum years of sun spots, which we have collected in three curves at the top for the two minimum years 1890 and 1902 and at the bottom for the maximum year 1894, so that these curves show the geographical distribution of the anomalies during the extremes of the solar activity. There is found a very interesting difference. In the minimum years the curves rise from the most northerly toward the most southerly station, whereas in the maximum year they sink. In both cases the anomalies are greatest at the northerly station and smallest at the southerly. On the whole there is a good agreement between the variations of temperature and of sun spots, except for the two most southerly stations where the relation is generally inverted.

A CONCLUSION

The principal result of our investigations on the relation between the variations in the solar activity and the variations in the temperature of the earth is therefore that there is a close connection between these two, but the variations in the solar activity have not at all

times the same action upon the temperature of the earth even at the same place. In all the regions of the earth which we have investigated the variations of meteorological elements go at times parallel with those of the sun spots, the prominences, or the disturbance of magnetic elements, and then with sudden change for a number of years proceed oppositely and perhaps then return for another long period of years to parellelism again. This follows also for the shorter periods of a few years, as well as for the longer eleven-year periods.

Furthermore we have found that in places which are near together, and in the same action sphere, as for example Bombay and Wellington, the temperature variations during a long period of years may go directly opposite to one another.

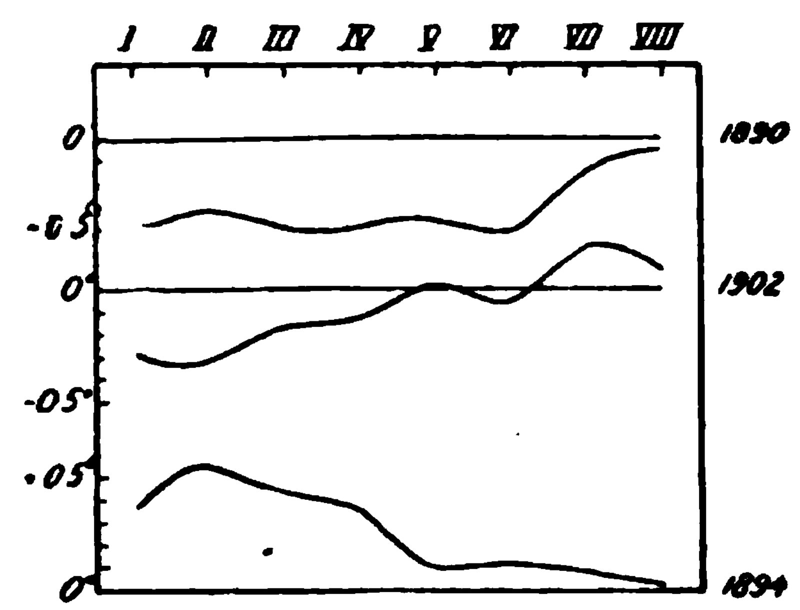

FIGURE 86. The distribution of temperature anomalies at Liepe's eight stations at sun spot minimum in 1890 and 1902 and in sun spot maximum in 1894.

NO DIRECT CONNECTION BETWEEN VARIATIONS IN THE SOLAR RADIATION AND TEMPERATURE VARIATIONS ON THE EARTH'S SURFACE

Although plainly the temperature variations of the earth must depend on variations of the solar activity, yet from what has been said it must be clearly borne in mind that the variations of the solar radiation are not the direct cause of the variations of the air temperature at the earth's surface and the variations on the surface temperature of the ocean.

As already mentioned, it has been suggested that the temperature variations depend on variations in the frequency of clouds in the earth's atmosphere or in the formation of ozone in the higher layers of the atmosphere (called the stratosphere) depending directly on variations of the solar activity and changes in the relations between the incoming and outgoing radiation of the earth. In case this is

correct there must plainly be great and sudden changes in the daily and yearly temperature amplitude at different parts of the earth and particularly we must expect that these will be most strongly marked in the tropics. But the investigations which we have summarized of the daily temperature amplitudes in several tropical stations show no secure indication that this is the case.

Only at Antananarivo and Fort de France the combined curves of daily amplitude which we have collected show considerable variations. The curve for the first named station (fig. 71, IV, T-A) shows no marked similarity with the sun spot curve or the prominence curve. To be sure it has a maximum between 1892 and 1895 that may have a certain similarity to the sun spot maximum, but its most conspicuous minima in 1891 and 1897, as well as the rise from 1897 to a maximum in the year 1908 and 1909, have little similarity to either the curves of sun spots or of prominences and just as little with the magnetic curves. The whole appearance of the curve is indeed very exceptional.

The curve for the temperature amplitude in Fort de France (fig. 71, VI, T-A) has more similarity with the curves of sun spots and prominences, having a minimum in the year 1900 and a rise in the years after. The maximum comes in the year 1907, that is, in the last year of sun spot maximum and exactly in that year when the prominences reached their maximum. In the earlier sun spot period the maximum of temperature amplitude falls between 1893 and 1894 very well with the sun spot maximum, but in this period there is a secondary maximum in the year 1897, and the sun spot period is therefore divided into two parts, a phenomenon which we have already often observed. A corresponding minimum we find also in the precipitation curve for 1897. It has the appearance as if in these cases there is really an increase in the daily temperature amplitude with simultaneous increase of sun spots.

At the other tropical stations which we have investigated, we can find, however, no well marked dependence between the sun spot curve and the curve for the daily amplitude. We have already spoken of this in regard to Batavia (see fig. 68). We find there that the daily amplitude increases with decreasing cloudiness, as is natural. The less the prevailing cloudiness the greater is the outgoing radiation and consequently the greater the amplitude of the temperature. We find also that the curve for the daily amplitude rises and falls about simultaneously with the temperature curve and the curve for the air pressure. That the latter would be the

case could also be expected, going on the assumption that a higher air pressure corresponds to a more cloudless sky. Any indication from this that the daily temperature amplitude in Batavia increases with increasing sun spots and prominences we do not find.

The daily temperature amplitude curve of Wellington (fig. 71, II, T-A) does not show anything definite. The curve appears to be somewhat irregular and shows a remarkable rise during the whole time from 1883 to 1905. This rise is, however, similar to a rise of the temperature curve for Batavia. It corresponds to a general decrease of the number of prominences from 1883, which is plainly shown in figure 69.

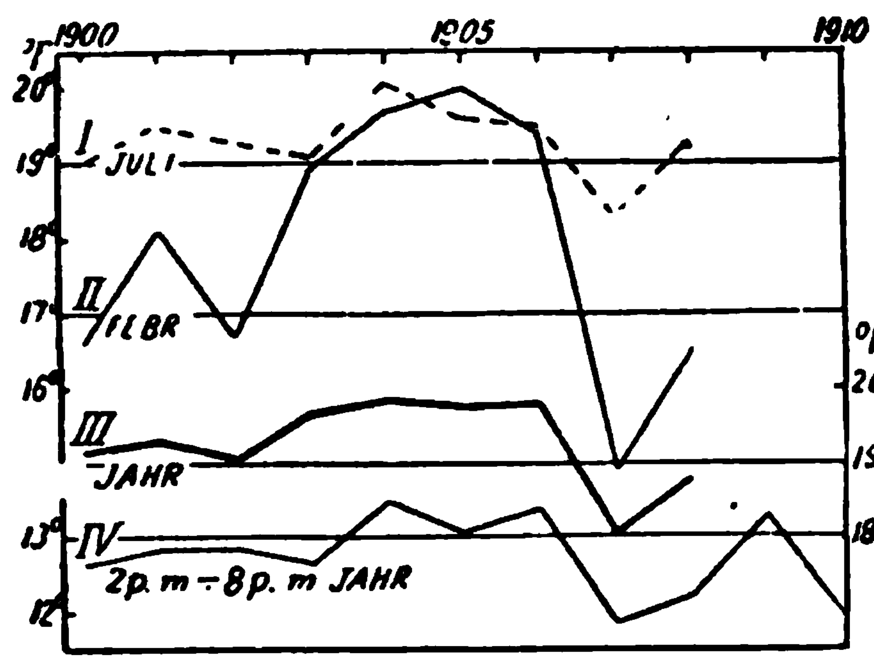

FIGURE 87. Difference between mean maxima and mean minima of temperature in degrees F. at Arequipa in July (I), February (II), and for all the year (III). IV: yearly mean of the difference between the temperatures at two o'clock and eight o'clock afternoon.

The curve for the daily temperature amplitude in Mauritius (fig. 71, III, T-A) also shows similarity with the air pressure curve, in so far as it has the same partial maxima that are found in the latter, and this could be expected according to what we have said above, in case a higher air pressure corresponds with a cloudless sky. However, there is no great similarity between this curve and the temperature curve for Mauritius and just as little with the sun spot curve.

At Port au Prince the curve of daily temperature amplitude (fig. 71, V, T-A) also shows similarity with the air pressure curve, in so far that they have at least partially the same maxima, but any great similarity with the temperature curve is not to be found and just as little with the sun spot curve, except that from 1900 to 1910 possibly the two go oppositely.

It may be thought, however, that at an *inland* station of the tropics the daily temperature amplitude would respond more directly

to solar changes, and therefore we have studied the published temperature data of Arctowski (1912). Here we have collected data for curves which show the variations of temperature amplitude (in Fahrenheit degrees) in February, July, and for the whole year in Arequipa, Peru (fig. 87). We find in February, which is in the southern summer, a well-marked maximum about the year 1905, but the strongly-marked minimum in 1907 that is found in all curves of the amplitude of this station does not fall in with the sun spot curve or with the prominence curve which has its maximum in this year.

If it should be objected that we are dealing here with another doubling of the sun spot period, it must be taken into account that this minimum in the year 1907 was considerably lower than the minimum in the years 1900 to 1902, when the sun spot minimum prevailed. At all events the agreement between the curves of temperature amplitude and the sun spot curve at this station is not good enough to base any considerable conclusion upon it.

THE YEARLY AMPLITUDE OF THE TEMPERATURE IN NORTH AMERICA

If great variations in the relation between the incoming radiation and the outgoing radiation of the earth take place from year to year, one would expect that these would be particularly noticeable in the inner parts of great continents, where the difference between winter and summer temperatures is great, since there the summer temperature is more strongly influenced by the incoming radiation and the winter temperature by the outgoing radiation. We have therefore examined the yearly amplitude, that is to say, the temperature difference between the warmest and coldest parts of the year, in four different regions of the United States. The result is given in curves I to IV of figure 88. It will be seen that the fluctuation on the Pacific coast (the Pacific states curve I) is considerably more regular than in the other three regions, and it goes for the most part oppositely to these. At the bottom of the figure are the curves S and P for sun spots and prominences, the latter according to observations at Rome and Catania. The reader will see that there is no distinct agreement between the four curves of yearly amplitude and these curves. The two temperature curves, II and III, show marked minima in the year 1890 which in curve IV is displaced to 1891. This is simultaneous with the minimum in the sun spots and the prominences. But on the other hand in the years 1901 and 1902 there is no corresponding marked mini-

mum in the temperature amplitude, although there is some indication of it in the curve IV for the interior states. This curve shows besides the halving of the eleven-year sun spot period with a minimum in the neighborhood of the sun spot minimum (see in this connection the years 1891 and 1902) and a minimum in the neighborhood of the sun spot maximum (compare the years 1884 and 1906) or at least near the middle of the eleven-year period (see 1896). In the last period, 1902 to 1913, there was a middle minimum so much

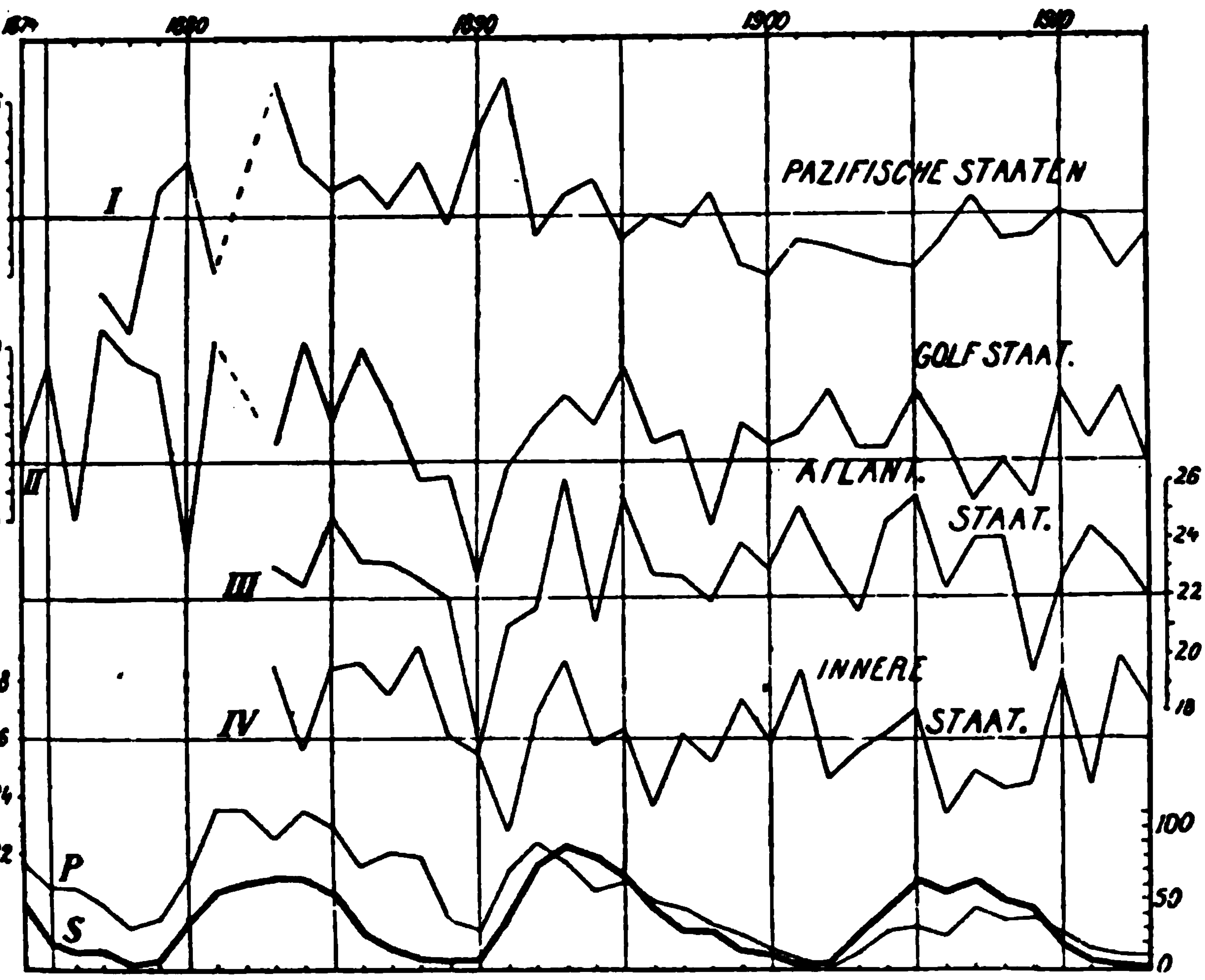

FIGURE 88. Temperature differences (in degrees Centigrade) between the warmest and coolest months of the year in four regions of the United States of America. I: in the most westerly states on the Pacific Coast. II: in the states on the Mexican Gulf. III: in the most easterly states on the Atlantic Coast. IV: in the inner states.

deeper than the others that at this period the curve IV on the whole goes oppositely to the sun spot curve.

In the curves II and III for the Gulf states and for the Atlantic coast states there is an indication of a similar halving of the eleven-year period, with some displacement of phase.

For these four regions of the United States we have also studied the variations of the average temperatures for the summer and for the winter. As representing the winter we have used the months December, January, and February, and for the summer, June, July,

and August. In figure 89 the weak lines show the variations in the average winter temperature. These are marked W and are drawn full. The summer temperature is given by the dotted lines marked S. The heavy lines S-W show the variations in the difference

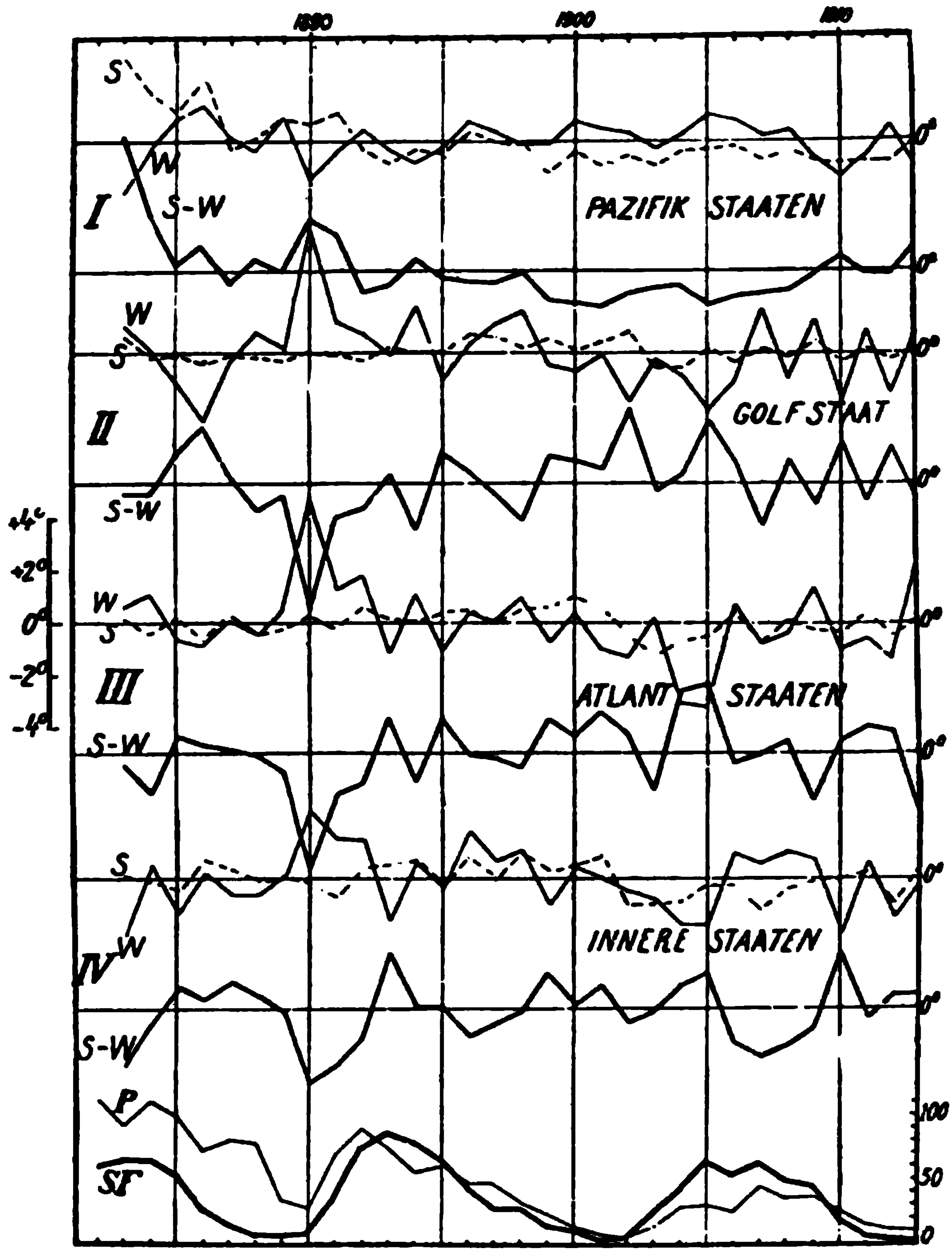

Figure 89. Temperature anomalies of the three summer months (curves S), the three winter months (curves W), and the difference between these anomalies for summer and winter (curves S-W). The lowest curve indicates the yearly mean of the daily number of prominences (P) according to observations in Rome and Catania, and for the relative sun spot numbers (SF).

between the temperatures of winter and summer. It is striking how much less the summer temperature varies on the whole from year to year than the winter temperature. It may be seen that the variations in both summer and winter temperature and in the difference between them are considerably less for the Pacific coast

(curves I) than for the other three regions (curves II to IV) and that here as in other relations before mentioned the variations on the Pacific coast are on the whole inverted to the variations of the other regions.

Since the winter temperature varies more than the summer temperature the curves (as the difference between them shows) are determined mostly by the winter temperatures. Hence the different curves on the whole give an inverted picture of the curve of winter temperatures.

We can now compare these various temperature curves with the curves for sun spots (SF) and prominences (P) at the bottom of the figure. In the Pacific region (curve I) where, as we have said, the variations are small, it seems as if the winter temperature is especially low in the neighborhood of sun spot minimum, particularly 1890, 1910 and 1913. On the other hand, the difference between the temperature in summer and winter at these times was relatively great, but the variations are all so small and irregular that nothing is to be concluded from them. In the other regions there is a quite distinct agreement between the temperature relations in the two typical year seasons and the sun spot variations. It appears that in the neighborhood of the sun spot minimum, as well as of sun spot maximum, there is a relatively high winter temperature and consequently a relatively small difference between summer and winter temperatures. There is furthermore an indication of a halving of the sun spot period as we have found earlier. It comes to view most clearly in the curves III S-W and IV S-W.

INCOMING AND OUTGOING RADIATION—DUST AND CLOUD FORMATION

Our investigations do not appear to support the assumption that variations in the temperature of the earth which accompany the sun spot period depend directly on variations in the relation between incoming and outgoing radiation of such a nature that the outgoing radiation at sun spot minimum is diminished and the temperature of the earth on this account increased. If this was correct we should certainly have found it more definitely indicated in our curves than we have done.

If the temperature variations at the earth's surface are caused by cosmic dust or volcanic ash in the atmosphere or by formation of clouds (called forth perhaps by variations in atmospheric pressure, which would be particularly active to diminish the temperature at the tropics), the solar radiation which reaches the earth would be dimin-

ished. Hence we should expect that the temperature amplitude would have the tendency to diminish at times of minimum mean temperature; for the heat which is communicated to the surface of the earth by the sun rays would vary more than the outgoing radiation, although this also would be diminished by the formation of clouds and by dust in the atmosphere. But any marked diminution in the daily or yearly amplitude of the temperatures at minimum of mean air temperature is in general not to be found in our curves or at least not to be found in that degree which would be expected.

PROOF OF THE FAILURE OF BLANFORD'S HYPOTHESIS SHOWN BY OBSERVATIONS IN THE INDIAN OCEAN

We have already remarked that the direct observations do not support Blanford's hypothesis, namely, that in consequence of great solar radiation at sun spot maximum the surface of the ocean is warmer than at sun spot minimum, and therefore increased evaporation produces greater cloudiness and more precipitation over the land which finally produces lower temperatures. We will now take up this point more in detail.

According to the observations which the Dutch have published for two 10° squares in the Indian Ocean between 0° and 10° north latitude and between 70° and 90° east longitude, we have drawn the curves in figure 90 for the anomalies of surface temperature (WT) for the two fields combined (curves III and VIII) also for the curves for the air temperature (T) for the same two ten degree squares (curves IV and IX), also the curves for the wind velocity (W), expressed according to Beaufort's scale without regard to the direction. These are curves VI and XI with scales inverted. Finally we give curves for the cloudiness (N), the curves VII and XII also with inverted scales. On the same figure at the top we have given in curves I and II the temperature (T) and the air pressure (P) in Mauritius and at the bottom of figure the curves XIII to XV for the air temperature (T), the air pressure (P), and wind velocity (W) for Batavia.

We see from this figure that the variations in the surface temperature and the air temperature in these parts of the Indian Ocean follow one another closely and show also a great agreement with the variations of the air temperature of Mauritius and Batavia. There are a few exceptions, as for instance, that the maximum in the air temperature of Mauritius in the year 1908 does not appear in the curves for the two 10° squares in the Indian Ocean, nor does it

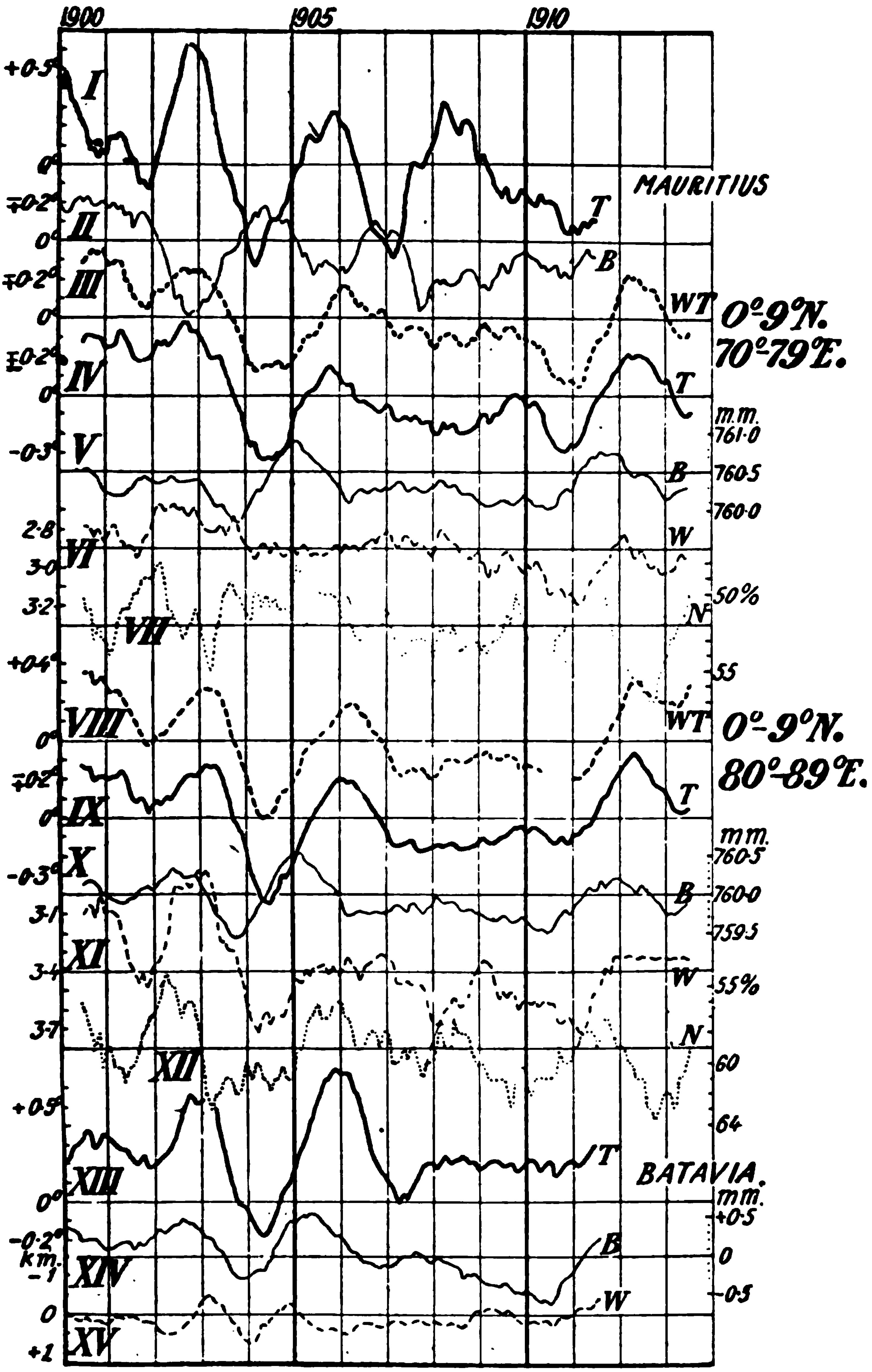

FIGURE 90. Curves for the two 10° squares (the Dutch tables, see above) in the Indian Ocean and for Mauritius and Batavia. T: air temperature. WT: surface temperature. B: air pressure. W: wind velocity. N: cloudiness. All values are consecutive twelve-month means.

occur in Batavia. The curves for the air pressure (P) for the two ocean fields agree nicely with the air pressure curve for Batavia, but not so completely with the air pressure curve for Mauritius. There appears a displacement such as we have already mentioned, and such as was noted by Chambers also, so that the variations in the further western regions occur earlier than those in the more eastern regions. The variations in the ocean fields are almost simultaneous with the variations in Batavia, but they are considerably later than the variations in Mauritius.

The curves for wind velocity (W) and cloudiness (N) show less marked agreement. The wind velocity varies on the whole (particularly in the most easterly of the two ocean fields) oppositely to the temperature. High wind velocities appear to accompany relatively low temperatures. Particularly in the most eastern ocean field, the variations in the wind velocity come somewhat before the variations of the temperature. The cloudiness appears to have a tendency in this field to go oppositely to the temperature and air pressure. But the variations in the cloudiness occur somewhat before the corresponding temperature variations, so that low cloudiness occurs before high temperature and vice versa.

The surprisingly good agreement between the variations in the meteorological elements in these ocean fields and the variations in the same meteorological elements over the land stations seems to prove definitely that no such opposite relationship between the variations of the ocean and the variations of the land exists as Blanford's theory assumes. These fields reach so far throughout the Indian Ocean that we must conclude that they represent the true oceanic relations.

We find on the whole that the different theories which we have mentioned above for the explanation for the variations of the temperature of the earth are scarcely in agreement with the results of our investigations either for the short period variations or for the longer period variations of eleven years. We must therefore seek elsewhere for a satisfactory explanation of these fluctuations.

A COMMON ERROR OF EARLIER AUTHORS

The error, according to our thought, which the most of the earlier authors have fallen into in their considerations of the possible cause of the temperature variations of the earth consists in that they have assumed that variations of the average temperature for the surface of the whole earth should act as a kind of a measure of the

variations in the solar emission of radiation itself, or in the solar radiation which is received at the earth's surface. They have not given proper weight to the consideration that a very great part of this radiation is absorbed in the higher layers of the atmosphere and that the distribution of temperature in the atmosphere of the earth plays a great and perhaps the greatest part in determining the temperature of the surface of the earth.

But this distribution of temperature in the atmosphere is in a high degree dependent upon the circulation of the atmosphere itself, and this again is dependent on the thermal emission of radiation of the sun, and perhaps also on other forms of energy radiation.

Because he did not consider the rôle of the circulation and temperature distribution in all the layers of the atmosphere an investigator like Newcomb has, for instance, according to our thought, fallen into an erroneous consideration of the problem. He maintains (1908, p. 382) that since the prevalence of magnetic storms shows that the "magnetic radiation" from the sun at maximum of sun spots is greatest (and therefore at the time when the terrestrial temperature is lowest) this gives ground for the assumption that the thermal action of the "magnetic radiation" is too small to have any direct influence on the observed meteorological phenomena. He thinks that on this account the magnetic, electrical and radio-active radiation of the sun can be completely left out of account.

The conclusion to which Newcomb (1908, p. 387) comes concerning the action of changes in the "solar constant" on the temperature of the surface of the earth seems also inadmissible. He believes the changes which are observed in high latitudes are not available to determine anything in relation to the changes in the solar activity, since such solar changes should first make themselves felt in the tropics. Therefore in case changes of the temperature in higher latitudes are greater than the changes in the tropics, they cannot be caused by variations in the solar activity itself, because this would obviously have the greatest effect in the vicinity of the equator.

He seems here to forget that the variations in the solar activity and in the "solar constant" (and also in the electrical radiation of the sun) are primarily affecting the higher layers of the air, and thereby altering the atmospheric circulation, not only in these higher layers, but also in the lower parts of the atmosphere. This can alter the temperatures of regions of higher latitude more than those of the tropics where the conditions are so stable.

EVAPORATION AND TEMPERATURE

According to our thought, erroneous views have also often been entertained on precipitation and evaporation. Authors have assumed that increased radiation and consequently increased temperature in the atmosphere must always correspond to increased evaporation and therefore increased precipitation. This is, however, not the case. Increased precipitation must, to be sure, on the whole accompany increased evaporation of the surface of the ocean or the surface of the land. Increased evaporation again one might think must be accompanied by increased temperature, but this is not always the case. Evaporation of the surface, whether of the ocean or of the land, is obviously dependent not only on the temperature, but also on the vertical and horizontal circulation of the atmosphere. Suppose there is little movement prevailing in the atmosphere, and its temperature is besides relatively high, and higher or at least not appreciably lower, than the temperature of the surface of the ocean. Under these circumstances, even if the temperature of both air and ocean were relatively high, there would be comparatively small evaporation since the air layers nearest the ocean surface would be very quickly saturated. Not being warmer than the air layers immediately above them they would not rise, but would lie upon the ocean and hinder further evaporation. On this account the evaporation can be relatively small at very high temperatures. This is exactly the condition which often occurs in summer when the air temperature is as high or even higher than the surface temperature.

If on the other hand the ocean surface is considerably warmer than the air, then even if there was not very great circulation in the atmosphere itself, vertical convection would arise in these conditions. The lowest air layer would be warmed and rise to greater heights and would be displaced by new layers which would in turn be loaded with moisture, and the evaporation would go on relatively fast even if no other motion of the air prevailed. That is the condition which occurs during the colder parts of the year very generally. It also happens that at these times a strong horizontal motion of the atmosphere prevails, so that one must assume that the evaporation at such times is quite considerable, and probably greater than that in the average of the warmest part of the year. Certainly the precipitation in winter is on the whole greater than that of summer. Also on this point Newcomb goes from not entirely correct assumptions when (1908, p. 394) he assumes that fluctuations of temperature on

the earth's surface are the primary cause of changes of precipitation, rainfall, or great movements of the air and fluctuations of the barometer. He comes to the final conclusion of his investigation "that all the ordinary phenomena of temperature, rainfall, and winds are due to purely terrestrial causes and that no changes occur in the sun's radiation which have any influence upon them." We on the contrary have found that the variations in the solar activity play a very great part in variations in air pressure, temperature, and precipitation, and have come to the conclusion that it is the air pressure distribution which in the first place is influenced and produces its secondary actions on all the other meteorological elements.

AIR PRESSURE DISTRIBUTION AND SOLAR ACTIVITY

In the investigations which we have described of the variations of the surface temperature of the ocean we found that these were prinicipally determined by the air pressure distribution, that is to say, by the winds of the individual months. This circumstance may give a hint where to find the cause which we are seeking.

Our investigations of the air pressure variations at the different meteorological stations on the land give, to be sure, no positive result indicating an explanation of the dependence between the atmospheric variations and the solar activity. On the other hand, it is not excluded that the explanation may be sought in the differences of atmospheric circulation; for the variations in the air pressure at individual stations as a rule give no real expression of the disturbances of the atmosphere, or the variations in atmospheric circulation over great regions. Such an indication must be found in the variations of the air pressure gradients. It would be easy to trace the variations in these gradients if one could only be sure of the difference in air pressure at two different stations, but we have already in another connection remarked upon the difficulties involved.

AIR PRESSURE DIFFERENCE COLOMBO-HYDERABAD

Nevertheless we have made such an investigation for a region which we have already treated extensively, determining for this purpose the air pressure difference for each month for Colombo, in Ceylon, and Hyderabad, in north India. It is to be remarked that the air pressure difference at these stations is inverted during the year since the air pressure maximum in winter lies north of India in interior Asia and in summer south of it, at which time interior Asia has an air pressure minimum. These conditions control the variations of the monsoon winds.

In figure 91, curve II gives the consecutive twelve-monthly means of air pressure difference between Colombo and Hyderabad. Curve III gives the consecutive twelve-monthly means of air temperature at Batavia. As the reader may see, the principal variations in these two curves go approximately in opposition. An increasing air pressure difference between Colombo and Hyderabad corresponds to a lower temperature at Batavia and vice versa. This was indeed to be expected; for if the yearly air temperature difference is small there would be in the course of such years a relatively small mean motion of the air, and so the temperature in Batavia would tend to rise and vice versa.

Curve I-b shows the air pressure variations in Bombay after 1900 according to Arctowski's publication of 1912, given in twelve-monthly consecutive smoothed values. As already stated this curve runs within this time interval oppositely to the temperature of Batavia, and follows the curve for the air pressure difference between Colombo and Hyderabad. If, however, we follow the temperature variations of Bombay further back in time we see, as already stated, that they go in the same direction as in Batavia, and therefore oppositely to the variations of the air pressure difference. This is shown by curve I-a for the years 1880-89 (after Arctowski, 1915) and also by curve IV. In the absence of twelve-monthly consecutive smoothed temperature values for the whole time interval mentioned, we give the curve by aid of the mean temperature values for the whole year. It is obviously not so accurate as those which depend upon twelve-monthly consecutive smoothed values, but nevertheless it gives the character of the variations. While the variations of this curve up to about 1896 go oppositely to the variations in the temperature curve of Batavia, before 1896, they are very similar to the variations of the Batavia curve, and so go oppositely to the variations in the air pressure difference between Colombo and Hyderabad.

Thus we find again the often appearing sudden reversal of the agreement between two curves of which one originally agrees with the other and then suddenly begins to march in the opposite direction. This often occurs in the comparison of two temperature curves at very different regions of the earth and also in the comparison between a temperature curve and an air pressure curve. We note in regard to it that the year 1896 in which the two curves we are discussing suddenly entered upon opposite courses corresponds with the time between 1894 and 1897, when the solar activity showed

sudden irregularities, so that the crossing of the curve of the widened known and unknown spectroscopic lines of Lockyer occurred. Most terrestrial and solar curves (see for example fig. 91, curves M and C, and curves of figs. 95 and 96) show also a well marked change of character about this time.

[illegible] 91. Curves *Ia* and *Ib:* temperature in Bombay according to Arctowski. II: anomalies of air temperature difference between Colombo and Hyderabad. III: temperature anomalies for [illegible]nia. IV: yearly mean of the temperature anomalies for Bombay. V: yearly mean the tem-
omalies for air pressure differences between the Azores maxi-
/II: temperature anomalies for all Norway. VIII: anomalies of
30° north 30° west and Sao Thiago. IX: anomalies of the sur-
VI (18° north 21° west). M: anomalies of the daily variation
nia, the successive twelve-month mean minus the successive
e left. R, C: consecutive twelve-month mean of the daily num-
ervations at Rome (R) and Catania (C). All curves except IV
nonth means.

gives the temperature variations in the high
dia in the Himalayas. The reader will
iations of this station go very well

with variations of the air pressure difference in the sense that high air pressure differences correspond to high temperatures and vice versa. This is what we would have expected from this mountain station.

In the same figure is a curve (VII) for the anomalies of the air temperature in Norway. Allowing for a phase displacement of some months, by which interval of time the temperature variations at Norway precede the air pressure difference between Colombo and Hyderabad, the reader will see that the curves II and VII on the whole show a certain agreement. That is, relatively high temperatures in Norway occur somewhat before relatively great air pressure differences in India and vice versa.

As we said in the beginning, no better results from such a comparison of temperature with air pressure differences between two fixed points was to be expected. Obviously it would be of very much greater weight if the variations in the pressure difference between the two *action centers* could be investigated, for these vary their position from year to year to some extent.

VARIATIONS OF THE NORTHEASTERLY TRADE WIND AND THE SURFACE TEMPERATURE

Liepe has emphasized the fact that variations in the strength of the northeast trade winds must call forth variations in the surface temperature of the stations which lie in the trade region. He thinks it is shown that the increased intensity of the trade wind as a rule causes a decrease of temperature and vice versa. As a measure of the variations in the strength of the trade winds he uses the air pressure difference between a point which lies 30° north latitude and 30° west longitude and the air pressure at Sao Thiago on the Cape Verde Islands.

Taking the anomalies of air pressure difference published by Liepe (1911, p. 482) we have smoothed them by taking twelve-monthly consecutive means and have represented them in curve VIII of figure 91 together with the curve IX for the temperature at Liepe's station VI which lies in the region of this pressure difference. The reader should note that this temperature curve is drawn inverted. The curve for the air pressure difference has already been given in figure 56, but drawn inverted. It will be seen that for all the fluctuations of the short period of years there is a very exact agreement between the air pressure gradient curve and the temperature curve for station VI and also with the temperature curves

for Liepe's stations III, IV, and V shown in figures 56 and 59. It can scarcely be doubted that the variations in the air pressure gradients, that is to say, in the intensity of the trade wind, is here an important cause of the temperature fluctuations within the observed fields which occur in intervals of a short number of years. It is very doubtful that, however, if this is true of those variations of longer periods of years.

We see in figure 91 that the curves VIII and IX for the earlier time up to 1892 lie close together. They then gradually separate from one another and afterwards approach again in the year 1902. The temperature at station VI and also at other of Liepe's stations was considerably higher in the time interval 1893 to 1902 than would be expected by reference to the curve of air pressure gradients.

This relation is yet more clearly shown in figure 85, where we have reduced the curves by two- and three-years smoothing. Curve B shows the air pressure gradients in the trade wind region and curves I to VIII the temperature at Liepe's stations. We see that here curve B goes very well with the temperature curve of Liepe's stations III to VI for the first part of the time up to 1892, but that after this time there is little agreement between the air pressure curve and the temperature curves. The combined two- and three-years' smoothing has eliminated the shorter fluctuations which in figure 91 and figure 56 show such great agreement. We must therefore assume that in this region other factors began to come into play after 1892. It might be that surface currents from the Canary Islands bringing down water from the north had changed the temperature. Liepe has remarked that temperature variations may occur in this manner. The temperatures at Liepe's station I and partly also at Liepe's station II were particularly high in the years 1893 to 1900. It might be thought that warmer water thus carried southwards would tend to hinder the depression of the temperatures corresponding to the winds.

Returning now again to figure 91, and comparing the curve VIII for the already mentioned air pressure gradients with the curve II for the difference in air pressure between Colombo and Hyderabad, we see that the variations in these two curves at corresponding times have a tendency to go oppositely. For instance, a small air pressure difference in India in the year 1897 coincides with a relatively great air pressure difference in the northeasterly trade wind. At other times they run in the same direction, as, for instance, when a great

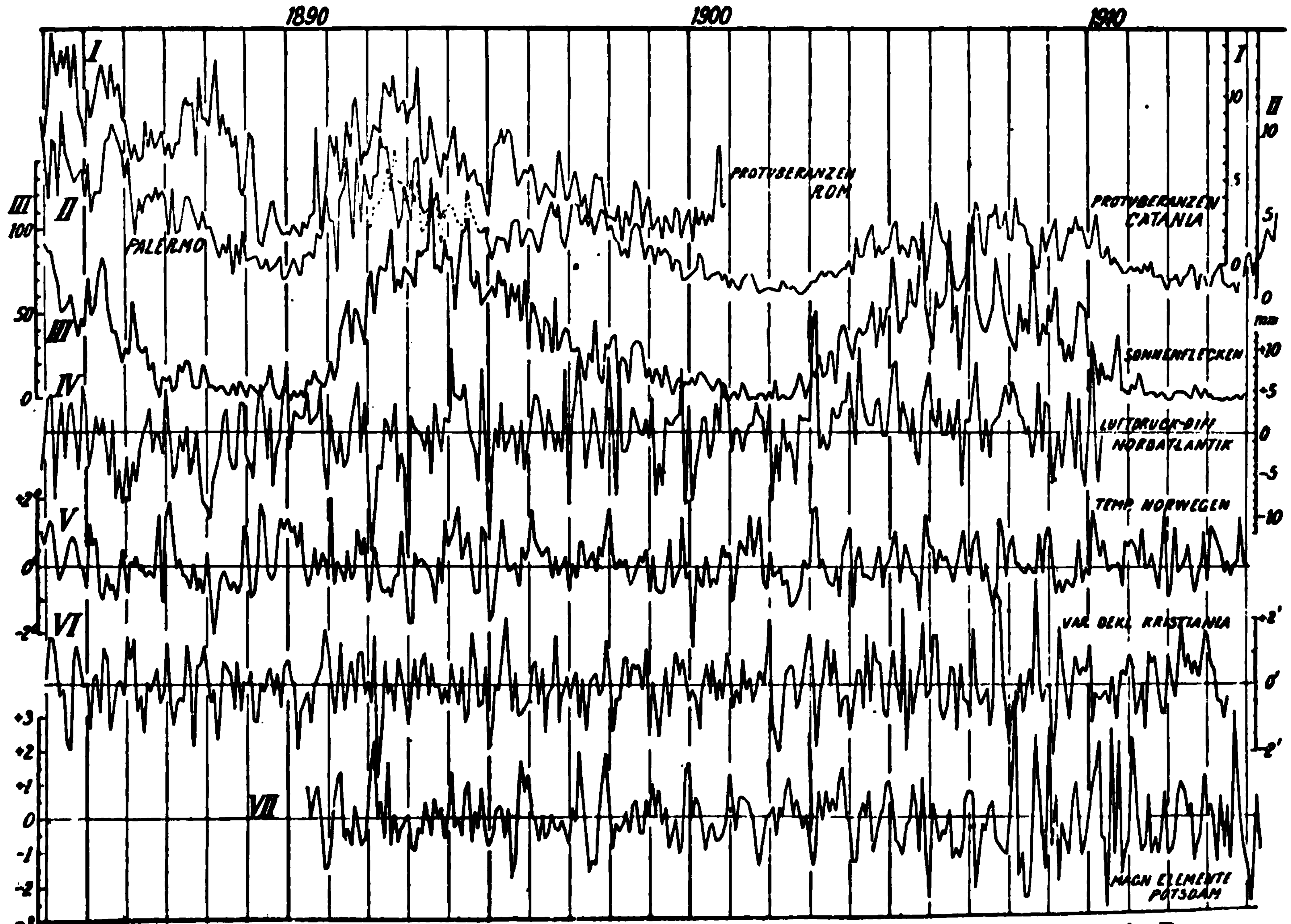

FIGURE 92. Monthly means. I: daily number of prominences according to observations in Rome. II: the same according to observations in Palermo and Catania. III: the sun spot relative numbers according to Wolfer. IV: the anomalies of the air pressure difference of the North Atlantic. V: the temperature anomalies in Norway. VI: the anomalies of the daily variation of declination in Christiania minus the successive twelve-month means. VII: the anomalies of the characteristic numbers of the three magnetic elements in Potsdam minus their successive twelve-monthly means.

air pressure difference in the northeast trade winds occurs in the years 1886 to 1887, and again 1889 to 1890 with corresponding features in the curve of Colombo-Hyderabad.

THE AIR PRESSURE DIFFERENCES OF THE NORTH ATLANTIC AND THE TEMPERATURE VARIATIONS

In order to get a closer view of the variations in the dynamics of the atmosphere it is obviously necessary to study the variations between the different action centers instead of only taking air pressure differences between some chosen fixed points. It must also be of importance to consider both the variations in the strength of the action centers and the variations in their position at the different times. In the first respect it should be investigated whether the difference between an air pressure maximum and the adjacent air pressure minimum would furnish approximate values for the disturbance of the atmosphere. For this purpose we now consider one of the most marked air pressure minimum of all the earth, namely the so-called Icelandic minimum and the adjacent region in the south, the so-called Azores air pressure maximum. Both have the advantage that they have very definite forms. They continue for the whole year, while the continental action centers mostly change from maximum to minimum between winter and summer.

In order to obtain an entirely satisfactory expression for the atmospheric condition over this part of the earth it would be necessary to study not only the difference between the pressure of these two action centers without regard to their position, but also to measure the distance between the centers, that is, the gradients, and the direction and the position of the lines of flow between them. Such an investigation would necessarily be very wide. We hope to undertake it later. Preliminarily we have confined ourselves to determining the difference of the intensity of pressure in the region of maximum and minimum only for a single month without regard to the variations in the positions. It appears that the air pressure variations in the maximum region are so small that the considerably greater variations in the minimum region would give alone by themselves almost the same result as if one should observe actually the difference between maxima and minima.

In this investigation we have employed charts of the average air pressure distribution over the Atlantic Ocean for each month which are published by the Meteorological Institute of Copenhagen and the Deutsche Seewarte in Hamburg. From these charts we

have taken the values of the highest and lowest isobars in these two action regions. Since the so-called Icelandic minimum in individual months may include two or three subordinate areas of minima, it is difficult to decide which of them shall be chosen in order to reach the desired homogeniety in the investigations. The most strongly marked minimum in an individual month may be wholly within the Barents Sea or even be forced over to the Kara Sea, or on the other hand it may be in Baffin's Bay or within the North American Arctic Archipelago. Still, only in exceptional cases the choice be doubtful.

FIGURE 93. Monthly means. I: the anomalies of the air pressure differences of the North Atlantic. II: the anomalies of the surface temperature in fields 30° to 39° west, 50° to 53° north, scale inverted. III: the same for the field 20° to 29° west, 53° to 57° north, scale inverted. IV: the same for the field from 0° to 9° west 58° to 59° north.

In curve IV, figure 92, we give the observed monthly values of the air pressure difference in the North Atlantic Ocean for the period 1885 to 1910. In curve V we give the monthly variations in the air temperature in all Norway. In figure 93 are shown by curve I, the monthly variations in the air pressure difference, and in curves II and III the monthly variations in the surface temperature in the Danish fields at 30° to 39° west longitude and 20° to 29° west longitude, both curves being inverted. Finally in curve IV we those of the fields 0° to 9° west longitude. In figure 94 given the curves of the above mentioned air pressure the North Atlantic, the air temperat face temperature in the thre tive twelve-monthly mea

If we consider first the last named curves it must be surprising what extraordinary agreement between the different curves here appears, particularly in curve I for the air pressure difference in the North Atlantic and curve II for the air temperature in all of Norway. These two curves agree even to the smallest feature, so that almost every small depression or wave in the curve of air pressure difference a little later occurs in the temperature curve for Norway. In other words this shows that the shorter fluctuations of a few years only in the air temperature in Norway depend principally on the air pressure difference in the North Atlantic, so that the air pressure gradients, that is, increase of atmospheric circulation over the Atlantic Ocean, corresponds to an increase of temperature in Norway and vice versa. For the variations of a longer time interval the matter may run otherwise, shown in curves I and II.

If we consider the relation of the surface temperature in the most westerly Danish fields (curves III and IV) and the air pressure difference over the North Atlantic Ocean more closely, we find the opposite case, namely, that an increase of the air pressure difference with an increase of atmospheric circulation over the Atlantic Ocean corresponds to a depression of the surface temperature for these Danish fields and vice versa. The reader should observe that the curves III and IV are inverted. In the most easterly Danish field, between 0° and 10° west longitude the relation is partly opposite. There an increase of the atmospheric circulation, in part at least, brings on a fall of temperature just as in Norway, only with less regularity, since the relations in this most easterly Danish field are partly a mixture of the relations which occur in Norway and in the westerly Danish fields.

We have already remarked the close agreement between the curves for this most easterly Danish field (and in part also for the field further westerly between 10° and 20° west longitude) and the curves for the fields further south in the easterly part of the Atlantic Ocean, as, for example, the curves for Petersson's stations I and II and Liepe's most northerly stations I, II, III. We have also spoken of the similarity between the February curve for the most easterly Danish field at 0° to 9° west longitude and the February curves for the most easterly of the regions investigated by us further south in the shipping course, Channel to New York, and also in the region, Portugal to the Azores. From all this we must draw the conclusion that the temperature rise over north Europe which follows an increased air circulation also holds for the surface temperatures

over the greater part of the more easterly regions of the Atlantic Ocean.

In this we find a good explanation of the partial opposition which we had found earlier between the temperature curve for the middle and more easterly parts of the Atlantic Ocean. That this relation of opposition is not complete, as we found, is furthermore explained because these more easterly fields farther south near the Channel and Portugal form a transition zone between two different action centers where the temperature variations have opposite courses. These regions fall now under the one, now under the other influence, in the manner which Hildebrandsson has already explained.

Further to the south in the region of the trades the temperature variations in the eastern part of the ocean run oppositely to the direction which they take farther north, since here, as we have already previously said, they are to a great extent dependent upon variations of the strength of the trade winds. An intensified trade wind causes a fall of temperature and vice versa. Now it is the case that variations in the northeast trade (that is, variations in the air pressure gradients in the region of the trades) coincide with variations of air pressure difference in the North Atlantic Ocean, as an examination of curves VIII and VI of figure 91 will show clearly. These two curves coincide simultaneously very well even in many of their smaller peculiarities. Since, however, the variations in the air pressure difference agree with the variations of the temperature in Norway, while on the other hand the variations of the air pressure gradients in the trade regions go oppositely to the variations at Liepe's stations in the trades, it follows that the temperature variations of the latter have an opposite direction to the temperature variations in Norway which is also shown by a comparison of the inverted curve IX for Liepe's station VI with the direct curve VII for the temperature in Norway shown in figure 91.

We see therefore that an increase in the air circulation works in opposite directions in different regions and these regions can often lie very near one another, as for example the most easterly Danish field at 0° to 9° west longitude and the most westerly Danish field at 20° to 29° and 30° to 39° west longitude. Such results warrant us in taking a closer view of the dependence of different types of temperature variations to which we have called attention and which at first sight seem subject to no law. The explanation of such relations is apparent from the examples we have given. An increased air circulation, which corresponds generally with an increase of the

southwesterly winds in the most northerly Atlantic Ocean and Europe, would produce an increase of temperature in these regions. This increased circulation would, however, at least as a rule, act in an opposite direction in the northern central parts of the North Atlantic Ocean, though the result depends obviously to a certain degree on the direction of the winds, as we have already said. Furthermore an intensification of the trades, which is associated with the increase of the air circulation, as mentioned above, would have the effect of causing the temperature of the ocean surface and of the air in the trade regions to fall.

As we have already said, the curve for the most westerly Danish field shows great similarity with the temperature curves of the same time interval for a series of meteorological stations in different parts of the earth, while on the other hand the Scandinavian curves show for many years similarity with temperature curves for other stations. From this we conclude that the observed variations in the North Atlantic centers are not local, but are an expression of variations widespread in the earth's atmosphere.

This conclusion is supported by an investigation of the curves of consecutive twelve-months means. The natural question is now whether these agreements occur in the shorter fluctuations from month to month. We shall clarify our view of this matter by investigation of the curves of figure 92 and figure 93. We see, for example, that the monthly fluctuations in air pressure gradients in the North Atlantic on the whole correspond to variations in the air temperature in Norway, but fall generally a month later (see the curves IV and V of fig. 92). The agreements are occasionally almost complete though at times not so good. These apparent disagreements of the relations may be actual or they may be attributed to errors in the air pressure differences, which are obtained by very rough methods.

We have already given the monthly variations of the temperature in Stockholm, comparing them with the variations in the surface temperature at the lighthouse stations along the Norwegian coast, and we found a close agreement which extended even to the most minute particulars. Since the variations in these regions agree completely with the variations in the temperature of all Norway, we must therefore conclude that fluctuations in air pressure gradients in the North Atlantic are accompanied by corresponding fluctuations in the temperature of all Scandinavia and in the coast water temperature of Norway. But the results of these fluctuations of

air pressure gradients show themselves first in the air temperature of Scandinavia and somewhat later in the water temperatures along the Norwegian coast, as we should, of course, have expected.

Considering now the curves of figure 93 we see that the agreement of the curve for the air pressure gradients over the North Atlantic Ocean with the curves for the Danish fields is less good with regard to individual peculiarities than that found in the above mentioned curves. But here also there are many cases of agreement and when we consider upon what slight material our temperature curves for the Danish fields rest we could scarcely have expected better.

It seems to be shown with great distinctness that the temperature variations not only in the surface of the Atlantic Ocean, but in the air temperature over north Europe follow even in the smallest details from month to month in general the variations in the air pressure gradients over the North Atlantic Ocean, which is to say, with changes in the circulation of the atmosphere as a whole.

AIR PRESSURE IN STYKKISHOLM AND TEMPERATURE IN STOCKHOLM

The above described series of air pressure differences over the North Atlantic Ocean extends over only a relatively small time interval from 1884 to 1910. In order to study the air pressure variations during a longer period of years and compare them with the temperatures in Scandinavia we have made the experiment of employing the air pressure observations in Stykkisholm in Iceland. This station lies near the usual position of the Iceland pressure minimum. J. Hann (1904) has collected the air pressure anomalies there for the time 1851 to 1900. We have computed consecutive twelve-months means from these anomalies and show them in curve I of figure 95 together with curve II for the temperature anomalies of the corresponding period for Stockholm. The reader will see that these two curves show a remarkably complete agreement, descending in a considerable degree even to the smallest details. This shows particularly clearly what a close dependence exists between the air pressure distribution over the North Atlantic Ocean and the temperature variations in Scandinavia.

VARIATIONS IN THE AIR PRESSURE GRADIENT AND IN THE SOLAR ACTIVITY

The question which now naturally arises is, whether there exists a dependence between the variations in the air pressure distribution of

the North Atlantic Ocean and the variations in the solar activity.

When we investigate the relation between solar activity and terrestrial phenomena we fall upon the difficulty that we have no certain indicator of the variations of the solar activity. It we compare the variations in the number of the prominences and in the magnetic elements of different kinds we find that the fluctuations of these phenomena coincidentally are not in agreement. Their curves follow somewhat different forms and we do not know which of them gives the most correct expression of the variations in the solar activity. More precisely expressed, we do not know which of them best represents that form of solar activity which has the greatest influence on the variations of our terrestrial phenomena. On this account we are even compelled to work somewhat in the dark until a greater clearness in these relations is brought about.[1]

Our curves for the air pressure difference, for the temperature, etc., show, as we have already said, that it is particularly the

[1] Krogness assumes that "the magnetic storminess" is a better expression of the variations of the solar activity than the sun spot numbers. If one, however, compares the magnetic observations for different parts of the earth he finds often a considerable disagreement. We find, for example, that the fluctuations in the daily variation of declination is often very unequal in Christiania, Prague, and Milan (see Wolfer Astronom. Mitt. No. C. for 1908). Also we find that the curves of the disturbance of the three magnetic elements in Potsdam differ very strongly from the curve of disturbance of daily variations of declination in Christiania. If these magnetic variations were a true index of the fluctuations in solar activity there must have been a greater similarity between them. Terrestrial conditions and partly purely local conditions obviously play so great part in the magnetc disturbances that the solar variations are more or less obscured by them, and it is difficult, or even impossible with our present knowledge, to form a satisfactory analysis of them. It is, however, probable that the magnetic perturbations within the zone of the Northern Lights is a fairly representative expression of the corresponding variations of the solar activity, at least a much better one than the perturbations which occur at lower latitudes where the effects are so much smaller. But within the zone of the Northern Lights we have no magnetic observational material that extends over a sufficient number of years to base upon it a study of the long period variations. The observations best adapted for our purpose have been carried on since 1843 at the observatory at Christiania, and relate to the average daily variations of magnetic declination. Prof. H. Geelmuyden has been of the greatest service to us, for he has with his own hands made an abstract of these observations for our disposal. In table 19-M will be found the monthly anomalies computed by us for the time since 1860. It is fortunate that now so good an observing station as that of the Haldde Observatory (Finnmark) has been erected within the circle of the Northern Lights, but thus far it has not been in existence long enough for its measurements to be used as the basis of a study of long period fluctuations.

shorter periods of a few years which come most prominently in the fluctuations, and that these shorter periods are adapted to partially cover the longer eleven-year period. Therefore it is necessary to investigate first the relation between these shorter period fluctuations in the air pressure difference and the corresponding shorter period variations in solar activity.

Let us now consider the consecutive twelve-monthly smoothed curves which show these fluctuations most clearly. In figure 96, curves II and III represent respectively the solar prominences and sun spots. In both curves we have eliminated the eleven-year periods by subtracting from the successive twelve-monthly means the successive thirty-six monthly means. In the same figure we give the corresponding curve I for the daily variations of declination in Christiania in which the eleven-year period is eliminated in the same way. As the reader will observe, these curves often do not run parallel.

If we now compare the sun spot curve and the prominence curve with curve IV for the air pressure difference in the North Atlantic and curves V and VI for the temperature in Norway and Stockholm, we find that it looks in general as if the first two curves were almost inverted from the last two in the time before 1897 or 1896 when in all the curves there were great variations present. For the time after the middle of the '90's and up to 1910 it has more the appearance of a direct agreement. Compare also figure 75 curve II for the temperature of the water along the Norwegian coast.

In figure 95 we give the same curve III for the sun spots and also the inverted curve IV for the prominences according to the Roman observations. The latter curve shows in part a very good agreement with curve I for the air pressure in Stykissholm. It is also worth noticing that the variations in this inverted prominence curve are partly a little later than the corresponding variations in the air pressure curve. With respect to the correspondences between these different curves, we must refer the reader more particularly to the figures.

We shall come later to these direct or inverted agreements between the terrestrial and solar shorter period fluctuations, but first we will follow the shorter fluctuations from month to month which are seen in curves of figure 92. Here we find something exactly similar. In the curves I and II we give the monthly variations in the daily number of prominences according to the observations in Rome, Palermo, and Catania. As the reader will see, there

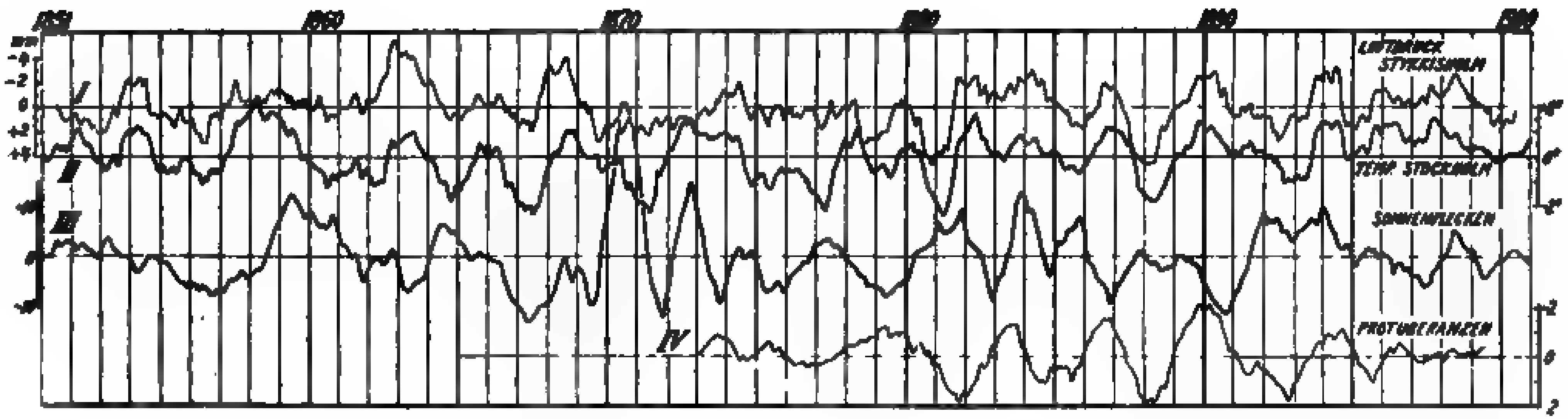

FIGURE 95. Twelve-month means. I: the air pressure anomaly :eland. II: temperature anomalies
in Stockholm. III: successive twelve-month means minus success h means for the relative numbers
of sun spots. IV: daily number of prominences according to ome, the scale on the right is in-
verted with increasing values downwards.

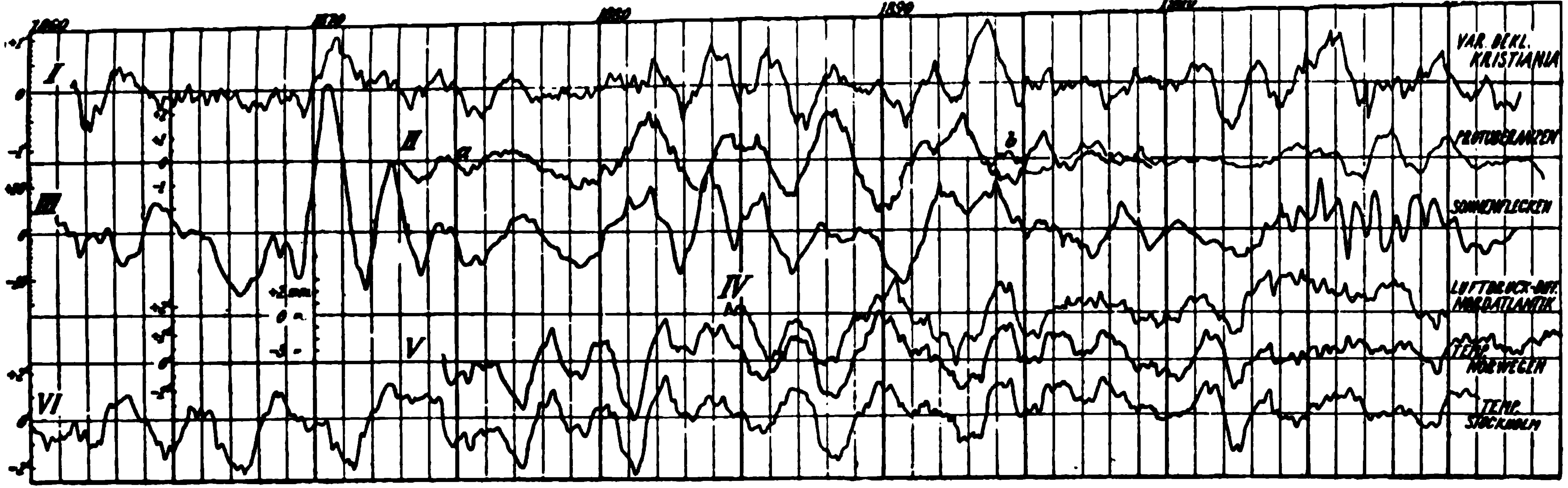

FIGURE 96. Successive twelve-month means minus successive thirty-six-month means. I: the daily declination variation in Christiania. II: the daily number of prominences according to observations in Rome (*a*) and in Catania (*b*). III: the relative sun spot numbers.
Successive twelve-month means. IV: the air pressure difference over the North Atlantic. V: the temperature anomalies in Norway. VI: the temperature anomalies in Stockholm.

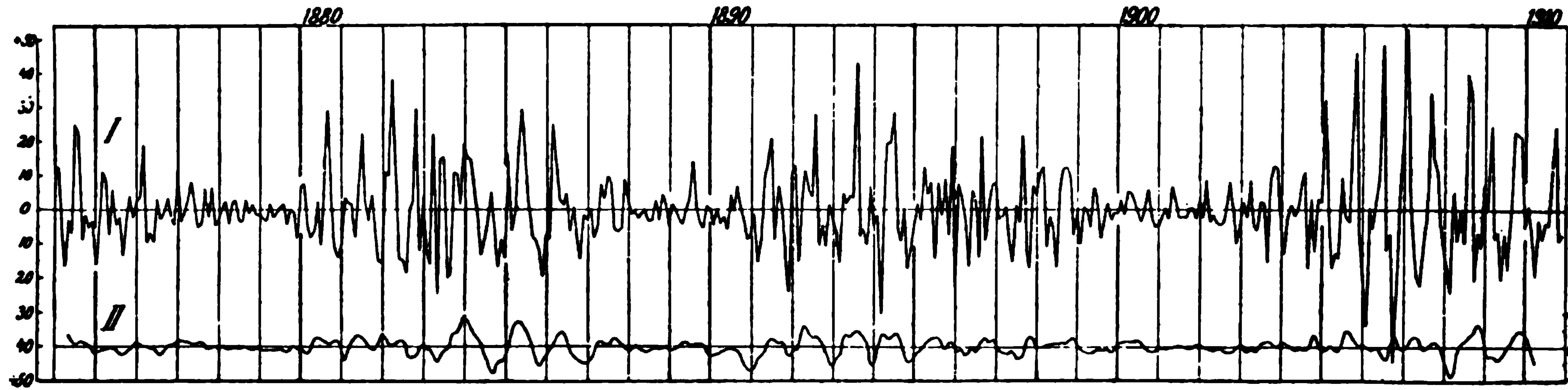

FIGURE 97. Curve I: monthly mean of the observed relative numbers of sun spots minus the twelve-month smoothed relative numbers according to Wolfer. II: successive eight-month means of the values which are given in curve I.

exists here a considerable disagreement between the various curves, and on this account alone there cannot be expected a very satisfactory result of a comparison of these curves with the curves IV and V for the air pressure difference, and for the air temperature in Norway. The reader will see that at certain times the fluctuations in these curves go oppositely to the fluctuations in the prominence curves, and at other times in the same direction; but if one imagines that there is part of the time a coincidence and at other times a displacement of one or two months, he sees for example that the variations in the curve for the air pressure differences for the time after 1903 goes quite well with the variations in the prominence curve for Catania.

In curve III we give the monthly variations in the sun spots; but the agreement between this curve and curve IV for the air pressure difference in the North Atlantic Ocean is also not very good. Occasionally we find that the variations from month to month in the sun spots go almost exactly inverted to the variations in the air pressure difference, and at other times, on the contrary, we find them in the same direction. It appears as if occasionally a displacement of a month or more was brought about, after which interval the variations in the air pressure difference follow the fluctuations in the sun spots. This is, for example, the case if one considers the great variations in the time after 1903.

In the curves VI and VII are shown the monthly anomalies for the variations of declination in Christiania and for the disturbance of the magnetic elements at Potsdam. The fluctuations for longer periods are eliminated because the successive twelve-monthly means have been subtracted from the directly observed mean values for each month.[1]

We see that these two curves present a rather fragmentary agreement. Compared with the curves for the air pressure difference in the North Atlantic and for
we find here also the same conditions
namely, that they run partly directly
oppositely. It is therefore difficult
matter. We refer for further details to
the relations are shown plainly to the

[1] Since the curves represent the
follows that the half year
variations are principally

EIGHT MONTHLY PERIODS IN THE SUN SPOTS AND IN THE AIR PRESSURE DIFFERENCE OVER THE NORTH ATLANTIC

Prof. Birkeland has pointed out that one might expect an eight-monthly period in the sun spots on account of the combined action of Venus and Jupiter, according as these stand in conjunction or in opposition. Such an eight-monthly period we have actually found in curve I for the sun spots which we give in figure 97. The curve shows the difference between the observed relative numbers and the twelve-monthly smoothed relative numbers for the sun spots as determined in Wolfer's publications in the Astronomische Mittelungen. The curve shows particularly great variations in the neighborhood of sun spot maxima and the greater excursions seem to have a regular time interval. This holds especially in the years 1904 to 1910 when the average time interval between these excursions amounted to eight months. As earlier remarked Krogness had found a similar eight-monthly period in the daily variations of the declination in Christiania.

Curve IV, figure 92, for the air pressure difference in the North Atlantic Ocean, shows also great excursions, with intervals between which correspond to the excursions we have noted in the curve of the sun spots. As the reader will see most clearly, in the latest maximum period there come, from one to two and occasionally three months after the eight-monthly excursions in the sun spot curve, corresponding excursions in the curve of air pressure difference. The same will also be found to a certain degree in the earlier maximum periods from 1891 to 1898, while on the other hand in the first maximum period in the years 1884, 1885, and 1886, no indication of such an agreement between the sun spot curve and the air pressure difference curve appears to be found. However, the observed agreements are as good as we could have expected in consideration of the scanty observational material and the faulty treatment of it. Furthermore the six-monthly and twelve-monthly periods which are found in meteorological phenomena tend partly to hide these assumed eight-month periods.

As we have said, the variations in the sun spots are particularly great at sun spot maximum. They are occasionally at sun spot minimum very small. Nevertheless the variations during sun spot minimum are associated with fairly great variations in the atmospheric and magnetic phenomena upon the earth. This can in part be explained from the fact that it is not clear that it is the greater or less absolute degree of intensity in the solar activity which influ-

ences the meteorological phenomena, but rather that variations in this intensity of solar activity are of decisive influence for the production of variations in the terrestrial phenomena.

TWO-YEAR PERIODS IN THE SUN SPOTS AND IN THE TEMPERATURE OF SCANDINAVIA

In the terrestrial magnetic elements there are found periods of six months and of twelve months. These rest on the different positions of the earth in relation to the sun during its yearly movements. Krogness has noted a very well-marked two-year period in the magnetic declination which may be ascribed to the accumulation of three periods of six, eight, and twelve months. Since twenty-four is a multiple of six, eight and twelve, the common action of these three single periods must produce a two-year period. Woikof and others have shown that a two-year period in meteorological relations often appears. We see an indication of it in many of our meteorlogical curves. It comes quite well into view in the temperature curves V and VI of figure 96 and in part in the air pressure curves figures 95, I, and 96, IV. But it is more important that a similar two-year period also occurs in the curves of the sun spots which are found in the same figures, curves III. If we take into account only the smaller depressions of this curve we find them very regularly each two years, namely in the years 1861, 1863, 1865, 1867, 1869, 1871, 1873, and 1875. In the year 1877 the depression in the curve III is lacking, but we find it in the curves V and VI of figure 96 and also in curve I of figure 95. Depressions are found also in the years 1879, 1881, 1882-3, 1884, 1886, 1888, 1890, 1892-3, 1894-5, 1897, 1899. Later, after 1901, it is more irregular. As a rule each second one of these minima is considerably more marked than the one lying between. So for example very marked minima occur in 1879, 1882-3, 1886, 1890, while the minima lying between in the years 1881, 1884, and 1888 are less marked and partly only slightly indicated. We, come in other words, to the result that the curve of sun spots as well as the temperature curves show rather well-marked two-years periods.

Curve IV, figure 96, for the air pressure in Stockholm, shows, for the sixty years of its duration, in the years after 1865 a pretty good direct agreement with the sun spot curve, and before 1865 with the magnetic curve I. We will carefully compare this air pressure curve for Stockholm and for a later time also curve V for Norway with the curve of sun spots. We see then that in the year 1877 a depression occurs in the temperature curves which is not found in

the sun spot curve. In the years 1885 and 1887 there is also no agreement.[1] But in general there is obviously throughout a quite good agreement between the sun spot curve and the temperature curve. A minimum in the one corresponds to a minimum in the other; occasionally, however, with some displacement of a few months. There is, the obvious difference, that the greater depressions which we have noted in the sun spot curve often correspond with quite small depressions in the temperature curve or vice versa that great depressions in the temperature curve come simultaneously with small depressions in the sun spot curve. As particularly characteristic examples, we refer to the variations in the years 1878 to 1884.

This characteristic relation of the distribution and magnitude of the minima in these different curves is the reason for the apparently opposite course which they show and which we have referred to above in relation to the time before the middle of the 90's. As an example of this, we point to the fact that a small minimum in the sun spot curve for 1888 corresponds to the very deep minimum in the air pressure curves, figures 95, I, and 96, IV, and in the temperature curves figures 96, V and VI, for the same year (assuming that the temperature minimum at the beginning of 1888 did not correspond to the sun spot minimum of a whole year earlier), whereas the deep minimum of the sun spot curve for 1890 corresponds to a very inconsiderable minimum in the other curves some months later. Furthermore, the small minimum in the sun spot curve in the years 1892-3 corresponds to a very well-marked minimum in the other curves at the corresponding time. This difference in the minima in the sun spot curve occurs towards the middle of the decade of the 90's, and that is the reason why greater direct agreement between the sun spot curve and the other curves seems to come in after this time.

It is worth remarking that in very many cases the maxima and minima of sun spot curves fall later than the corresponding maxima and minima of the air pressure and temperature curves. In the time from 1851 to 1865 the sun spot curve (fig. 95, III) and the meteorological curves (fig. 95, I and II) are very different and go in part oppositely to one another.

[1] If we consider, however, the magnetic curve I we find that in this time there was a quite good agreement between it and the temperature curves, if we admit a displacement of a few months. Also a direct agreement could be found between the sun spot curve and the temperature curves for these years if we should admit a displacement of about a year.

POSSIBLE ONE-YEAR PERIOD IN THE SUN SPOTS

It is yet clearer that apparently there is also a period of one year in the variation of the sun spots. Curve II of figure 96 shows a very distinct one-year period. This curve is the result of a consecutive eight-monthly smoothing of the differences which are given in curve I as above stated. The one-year period is particularly well shown in the interval 1890 to 1895. It is, however, possible that this period is accidental and results from the incompleteness of the observations. In the years 1890 to 1895 there exists a minimum for this curve in midwinter, or exactly at that time of year when the observations of sun spots at Zurich are on the whole least complete.

VARIOUS PERIODS

We have earlier remarked that in several meteorological elements, for example at Batavia, there appears to be a period whose average length is 32 to 33 months. That is about two and three-quarters years. This apparent period, like the eleven-year period, is subject to differences of length and ranges between two years and three or even four years. It is questionable whether this period depends upon a combination of several elementary periods which perhaps may be associated with corresponding periods on the sun. We have already remarked that a two-year sun spot period seems to be recognizable and we have also noted that it was found by the two Lockyers that there is a period in the solar activity of about 3.7 years. They find it both in the prominences and in the variations of the spectroscopic lines of the sun spots, as also in the heliographic latitude of the sun spots. Such a period in the solar activity of three to four years appears also in several of our curves. If, however, the sun spot periods of two years and between three and four years make themselves felt in the meteorological phenomena we could obtain from this a fairly close relation with different time intervals, of which, however, the average duration may very well be about two and three-fourths years.

SECULAR VARIATIONS IN SOLAR ACTIVITY AND IN METEOROLOGICAL RELATIONS

We have not treated of the very long period or secular variations but yet we will mention some peculiarities in several of our curves which are of interest in connection with the question of long periods. Many of our graphical representations show the relations between

sun spots and prominences, as figures 69, 88, 89, and others. For example, in figure 88 we see that the eleven-year period in the prominence curve comes out very clearly. The reader will see, however, that the three periods from 1878 to 1913 are very differently formed. In the first of these three periods there was a very great average number of prominences, in the next considerably less, and in the last relatively very few. The smoothed curve for the prominences shows therefore a clear decrease for this time interval of thirty-five years. It is plainly a part of a secular period in the solar activity. It appears that a similar sinking or corresponding rise occurred in several of our meteorological curves. We have already remarked that the temperature amplitude in Wellington (fig. 71) and the air pressure in Batavia (fig. 69) showed such changes. A direct or inverted agreement between the solar and terrestrial phenomena with respect to very long periods is indicated by still other curves. So, for example, in the curve for the temperature amplitude of North America (fig. 88 and also fig. 89) particularly in the Pacific states, but also in the Gulf states and in the inner states, the amplitude has on the whole during the three above mentioned eleven-year periods gradually become less, as well also as the air temperature itself on the west coast of the United States (fig. 64 curve I). Other examples could be cited which point to such secular changes in the meteorological phenomena in correspondence with solar changes.

CLOSE RELATION BETWEEN THE VARIATIONS IN SOLAR ACTIVITY AND IN METEOROLOGICAL ELEMENTS.

As a general result of our investigations we can here only remark that certainly a very close relation exists between variations in the solar activity and variations in the meteorological phenomena of the earth. Even short interval variations in the radiation of the sun are shown very distinctly in our meteorological phenomena and in the surface temperature of the ocean. They act through variations of the air pressure distribution, but the expression on the earth may take different directions according to conditions, running inverted to the solar variations or parallel to them.

This close dependence between the variations of the solar activity and the variations of the meteorological phenomena is shown not so much by the general correlation of our curves of figures 95 and 96 as by the sudden and extraordinary change of character which all of these curves of the solar and the terrestrial phenomena present in the middle of the decade of the 90's.

XIII. CONCLUSION

The point of departure in these investigations was the wish to investigate more closely some of the yearly temperature variations in the North Atlantic Ocean. We have seen that such variations are present and that they are very considerable and extend over great regions in common. They can be ascribed in greater part to the action of the air pressure distribution, that is to say, the winds. In order to understand the occurrence and the nature of the variations, meteorological variations must therefore be closely studied. These can be understood only when the atmosphere as a whole is investigated, and we are therefore led to make a very wide investigation.

Hitherto these extensive investigations have shown us that different groups of regions vary intact in a definite direction, while another group of regions varies in an opposite sense, and that again still other regions show transition phenomena, partly on account of phase displacements and partly on account of mixed relationships to the primary groups. All this gives us a variegated picture of the meteorological fluctuations, but out of this same variegated picture we find also by a proper analysis the influence of the variations in the solar activity which in all probability make themselves felt first in the higher layers of the atmosphere and thereby produces disturbances which again introduce changes in the lower layers. Such dynamic changes will take different courses in respect to the temperature, cloudiness, precipitation, etc., at different stations of the earth. But it seems possible by a thorough evaluation of available observational material to work out sure and general rules to cover the phenomena.

The present work is to be regarded only as an introduction to such more thorough investigations, and we must postpone a clarification of many of the questions raised here to later publications. Among them is the regulating action which the thermal condition of the ocean exercises upon the air circulation and the air temperature.

POSTSCRIPT

Our researches described above were finished during the winter 1916-1917, and our report was published by the Society of Science in Christiania.[1] Since that time we have received from Dr. C. G. ABBOT several papers that are of the greatest importance for our investigations. We may especially mention "On the Distribution of Radiation over the Sun's Disk and New Evidences of the Solar Variability" by C. G. Abbot, F. E. Fowle, and L. B. Aldrich [1916]; "Arequipa Pyrheliometry" by C. G. Abbot [1916]; "The Sun and the Weather" by C. G. Abbot [1917]; "Effect of Short Period Variations of Solar Radiation on the Earth's Atmosphere" by H. Helm CLAYTON [1917]. From Dr. L. A. BAUER we have also received two interesting papers: "The Local Magnetic Constant and its Variations" [1914] and "Solar Radiation and Terrestrial Magnetism" [1915].

By the various investigations described in these papers it is now established beyond doubt that on the one side the radiation of heat from the sun varies not only from year to year more or less periodically in a similar way as the sun spots, but there are also very great fluctuations in the radiation within short intervals of a few days, and on the other side it is shown that correlations exist between these fluctuations in the solar radiation and meteorological and magnetic changes on the earth.

INVESTIGATIONS ON FLUCTUATIONS IN SOLAR RADIATION BY ABBOT, FOWLE, AND ALDRICH

In their paper: "On the Distribution of Radiation over the Sun's Disk" (by C. G. Abbot, F. E. Fowle, and L. B. Aldrich) the authors prove that there is a great difference in the distribution over the sun's disk of the various solar rays. The contrast of brightness between the center and the edge of the sun is greatest for short wave lengths and diminishes as one comes to the red and infra-red. "There are, however, slight but significant differences between the mean results of different years," greater contrast of brightness

[1] Skrifter utgit av Videnskapsselskapet i Kristiania 1916. I Matem.—Naturv. Klasse. Vol. I, No. 9. Kristiania, 1917.

prevailing probably along with greater solar radiation at times of high solar activity. Thus in 1913, when there was a minimum of solar radiation (and also an exceptionally developed minimum of sun spots), the contrast of brightness between the center of the sun's disk and the edge was decidedly less than in the years 1914 and 1917, when there was evidently higher solar activity indicated by greater solar radiation (greater "solar constant"). "Besides these long-period changes there appear to be small changes of contrast from day to day, correlated with the changes of solar radiation heretofore discovered by the authors. For this type of changes increased contrast is associated with decreased solar radiation."

The authors are thus "led to consider two causes of change existing in the sun. One, going with increased solar activity, they regard to be increased effective solar temperature, which naturally produces increased radiation and increased contrast. The other, altering from day to day, they regard to be increased transparency of the outer solar envelope, which naturally produces increased radiation but decreased contrast. All these changes are greater for shorter wave lengths."

It may also be of some interest to mention here that according to the observations made during the year 1913 there should have been a sudden change in the solar radiation on September 23, when the solar constant and solar contrast values fell off and remained comparatively low during the rest of that season. At the same time "a marked change in the distribution and total amount of the water vapor in the atmosphere took place. The values of precipitable water in the atmosphere were far above the normal until September 23, and from then to the end of the period of observation generally about normal or a little below. A similar change is indicated, but not in so great a degree, by the observations with the wet and dry thermometers. The temperature also fell at the same critical time.

In his paper on "Arequipa Pyrheliometry" Dr. ABBOT discusses the observations made with the silver-disk pyrheliometer and nearly simultaneous measurements of atmospheric humidity made from August, 1912, to the end of March, 1915, at Arequipa, Peru, at the station of the Harvard College Observatory. We find that the Arequipa results fully confirm the variability of the sun both from year to year and from day to day, shown by investigations at Mount Wilson and elsewhere. The monthly mean values of the Arequipa observations also show remarkably close connections between the solar constant (solar radiation) and vapor pressure of the terrestrial atmosphere.

DR. BAUER ON SOLAR RADIATION AND TERRESTRIAL MAGNETISM

In his paper of 1915, Dr. Bauer finds a remarkable correlation between the changes in solar radiation, as shown by values of the solar constant possessing the requisite accuracy, and the changes in the Earth's magnetism. This is the case not only with the more or less sporadic changes from day to day, but also with the annual changes of the solar constant and the annual magnetic changes. " Since the solar constant changes occur only approximately in accordance with sun spot activity, and since the magnetic changes are found to conform closely to those in the solar constant, an explanation is found as to why the irregularities in the magnetic secular change do not always synchronize with changes in solar activity as measured by the sun spot numbers, nor correspond in magnitude to them." " The relation between changes in solar constant and magnetic constant is of such a definite character as to make it appear that one set of changes may furnish an effective control over the other." " Just how far changes in solar constant," as measured by the pyrheliometer, " may be taken as a true measure of those changes in the sun's activity, which really are the cause, directly and indirectly, of the magnetic changes, requires further investigation." Dr. Bauer also finds that the magnetic effects observed during total solar eclipses are in general harmony with the magnetic changes correlated with changes in the solar constant, as measured by the pyrheliometer.

DR. ABBOT ON FLUCTUATIONS IN SOLAR RADIATION, SUN SPOTS, AND TERRESTRIAL TEMPERATURE

In his paper on " The Sun and the Weather " Dr. ABBOT [1917] gives a comparison between the mean annual values of the solar constant as obtained by the observations at Mount Wilson for the years from 1905 to 1915 (except 1907) and the relative numbers of the sun spots. He found that the maximum mean annual value of the solar constant observed occurred in 1905 when there also was a maximum of sun spots, and the minimum annual value of the solar constant occurred in 1913 when there was an exceptional minimum of sun spots. But otherwise the fluctuations in the value of the solar constant do not always correspond with the fluctuations in the sun spot numbers. There is an especially marked disagreement in this respect in the values obtained for 1912 when the solar constant had a comparatively high value while the sun spot number was near its minimum. But on the whole it may be said that a low

solar constant generally corresponds to a low number of sun spots, and as a general result Dr. Abbot comes to the conclusion that an increase of 25 sun spot numbers may be attended by 1 per cent increase of solar radiation. If this be correct, Dr. Abbot finds that as the average range of sun spot numbers in the 15 sun spot cycles from the year 1750 to the year 1906 was 90, so we may expect that an average sun spot maximum is attended with 3.6 per cent more emission of solar radiation than the minimum of sun spot activity. According to computations made by Dr. Abbot, this might be expected to be attended with a general *increase* of terrestrial temperature of 2.5° C.

Dr. Abbot has also kindly sent us the measurements of the solar constant made at Mount Wilson during the months June to October, 1916. The mean value of the solar constant was 1.955; the mean relative number of sun spots that year was 50, which agrees well with the value of the solar constant, according to Dr. Abbot's conclusions.

DR. CLAYTON'S INVESTIGATIONS ON CORRELATION BETWEEN SOLAR RADIATION AND TERRESTRIAL TEMPERATURE

Of special interest for our researches is the paper by DR. H. HELM CLAYTON, of Argentina, on the "effect of short-period variations of solar radiations on the earth's atmosphere," given us by Dr. Abbot, in which the author definitely proves that there is an intimate relation between the short-period variations in the solar constant, as measured at Mount Wilson, and the variations of air temperature at several meteorological stations at the earth's surface.

By using the method of correlation, as worked out by Karl Pearson, Dr. Clayton first makes a comparison between the changes of the solar constant, as observed at Mount Wilson, and the changes of temperature at Pilar in Argentina during the months July to November, 1913, and the months from June to October, 1914. He found that an increase of the solar constant was regularly followed by an increase of the temperature at Pilar. The maximum correlation follows one to two days after the corresponding solar values.

By using the same method, Dr. Clayton also determined for 29 other stations, distributed over the globe, the correlation coefficients connecting temperatures with solar constant values, obtained at Mount Wilson in 1913 and 1914. He found that at some places there was decided positive correlation, *i. e. increase* of temperature follows *increase* of solar radiation, while at other places there was

a negative correlation, *i. e., decrease* of temperature follows *increase* of solar radiation. He came to the conclusion that the stations with positive correlation are distributed along certain belts round the earth: one belt in the tropic regions and two others in the arctic and antarctic regions. Between these belts there are two other belts with negative correlation, corresponding chiefly to the temperate zones and partly to the sub-tropical zones. In the belts with positive correlation the maximum temperatures follow about one or two days after the maximum of solar radiation. In the zones with negative correlation the maximum effect of the changes in the solar radiation follows after three or four days.

By computing the consecutive five-day means of the daily values Dr. Clayton has plotted smoothed curves of the solar constant and of the temperature at several meteorological stations, for the months September to November, 1913. The temperature curves show great resemblance to the curve of the solar constant. At five stations, where the correlation was positive, there is a direct agreement between the temperature curves and the solar curve. At two other stations, where there was a negative correlation, the temperature curves are inverted. But in some cases, especially at Stykkisholm, Iceland, and Sacramento, California, the temperature curves show direct agreement with the solar curve for some part of the period investigated; but then suddenly the agreement changes to be inverted or vice versa. As will be seen, this is a phenomenon which corresponds in a remarkable way to the relations we have found to exist between the temperature curves for a great many stations and the sun spot curve, during long periods. We found, for instance, that the consecutive twelve-month means of the temperature at different stations could, during a long series of years, vary directly as the sun spot numbers, but then they suddenly changed, and during a subsequent long series of years they varied inversely as the sun spot numbers, or vice versa. We also found that in some regions of the earth the temperature curves varied generally directly as the sun spot numbers, while in other regions of the world the temperature curves varied inversely as the sun spot numbers; and finally in some regions the temperature curves were mixtures of these two types of curves. The temperature varied partly directly, and partly inversely as the sun spot numbers. Dr. Clayton's curves of the five-day means of temperature at various stations seem to indicate that there is exactly the same difference of type between these curves as compared with the curve of the five-day means of the solar radiation.

Dr. Clayton takes it for granted that the variations in the solar radiation must have a direct effect upon the temperature at the earth's surface, and he consequently thinks that in a region where there is a positive correlation between the variations in temperature, and the variations in solar radiation, an increase of temperature is directly due to an increase of solar radiation and vice versa. The negative correlation in other parts of the world he, however, thinks to be a secondary result of the changes in solar activity. As far as we understand him this must be caused chiefly by the transport of colder air from higher latitudes. He considers the most probable explanation to be "that tropical areas, and especially the tropical land areas, are the parts most heated by the increase of solar radiation. This heating causes an expansion of the air of the tropics and an overflow toward the temperate zones, particularly towards the cooler ocean areas in this zone. The final result would be a fall of pressure in the tropics and a rise in the temperate regions causing an intensification of the normal pressure belts of the earth." He consequently examined the variations in the pressure at several stations in various parts of the globe, and comes to the conclusion that these pressure variations really verify the correctness of his view. The stations examined are, however, too few to base any real conclusions on, and the correlations between the pressure variations and the variations in solar radiation are in most cases very small. He thinks, however, that this indicates "that the pressure changes are the result of the temperature changes induced in the air by variation of solar radiation."

With his view of the causes of the temperature changes, Dr. Clayton has some difficulty in explaining how it is that "the effect of the solar change does vary from negative to positive at the same place, and while there may be a seasonable change there are also changes which cannot be explained in this way, and the reason for which remains yet to be found." He suggests, however, that "these diverse effects appear to be associated in some way with shifts in the centers of action in the atmosphere, as for example the shift of the anticyclonic center in the Atlantic and Pacific oceans, and that of the low pressure center near Iceland and the Aleutian Islands."

He furthermore says: "I am led to infer that an oscillation in the areas of positive and negative departures is characteristic of all effects of solar changes in the earth's atmosphere, and has been one of the reasons why the relation between atmospheric phenomena has been difficult to detect, and why periodic changes of all kinds have been masked."

For the months examined in the year 1913, Dr. Clayton thinks that he finds a period of about 22 days in the solar radiation as well as in the temperature at Buenos Aires, and, especially in the solar radiation he finds another shorter period of between 11 and 14 days.

Dr. Clayton sums up the results of his investigations thus:

"1. There is an intimate relation between the solar changes and meteorological changes of short period.

"2. There is a class of meteorological changes which have their origin in equatorial regions, and by a transference of air probably in the upper layers, are felt within a few days in higher latitudes. These changes are the complement of the complex meteorological drift which goes from west to east in temperate latitudes with a component of motion from Pole to Equator in both hemispheres."

Dr. Clayton does not expressly say whether, according to his view, the positive correlation in the arctic regions is directly due to the variations in the solar insulation, or whether it may be due to the above-mentioned transference of air from the equatorial regions probably in the upper layers which should be felt "within a few days in higher latitudes."

DR. CLAYTON'S VALUES OF THE CORRELATION FACTOR ARE NOT DIRECTLY DUE TO THE EFFECT OF SOLAR RADIATION ON TERRESTRIAL TEMPERATURE, BUT TO ITS EFFECT ON THE DISTRIBUTION OF PRESSURE.

It is evident that though the correlation factors found by Dr. Clayton are not very great, still most of them are perfectly certain. We do not, however, agree with the author that according to his investigations the regions with positive correlation and the regions with negative correlations may be assumed to be arranged in belts round the globe. By considering the correlations between the daily variations of solar activity and of temperature at the earth's surface at the 30 stations investigated by Dr. Clayton, we come much more to the conclusion that the occurrence of positive or negative correlations at these stations depends chiefly on their situation with regard to the centers of pressure maxima and minima of the atmosphere, in the same way as we have found it to be the case with the monthly and annual variations of temperature at the earth's surface in the various regions of the globe.

As the temperature of a region is essentially influenced by the prevailing winds, *i. e.*, by the mean barometric gradient, we must expect that in regions where the normal temperature is low as compared with neighboring regions in the same latitude, an increase

of the gradient will cause a sinking of the temperature, while in regions with comparatively high normal temperature an increase of the gradient will cause a rising temperature.

We must consequently conclude that at all stations, whether in the tropics, or in the temperate zones, or in the arctic regions, the fluctuations in the solar activity, by effecting changes in the distribution of air pressure and in the circulation of the atmosphere will cause changes of the temperature at the earth's surface according to the situation of the place. Let us examine some of Dr. Clayton's stations from this point of view. *Pilar,* in Argentina, is situated far outside the tropical regions in 31° 39′ S. 63° 5′ W. It should consequently, according to Dr. Clayton's theory, be expected to have a negative correlation, but it has a comparatively well developed positive correlation. This station is, however, during the months of July to November, situated on the western side of the center of action (the high pressure region of the South Atlantic). An increase of this pressure maximum, by increased solar activity, might therefore be expected to bring more northerly winds and consequently higher temperatures in this region.

Another station, *Bathurst,* in Gambia, on the west coast of Africa, is situated well inside the tropics, in latitude 13° 24′ N. 16° 36′ W., and might consequently, according to Dr. Clayton's views, be expected to have positive correlation; but he finds it nevertheless to have a very well developed negative correlation. This is, however, easily understood, considering that the station is situated on the southeastern side of the North Atlantic pressure maximum, in the region of the northeastern trade winds. An increase of the center of action, by increased solar activity, will increase the trade winds and lower the temperature.

At the station *Zungeru* in Nigeria, 9° 49′ N., and 6° 10′ E., the correlation is, however, positive. In this region there are probably no very strong prevailing winds during autumn, and an increased solar activity may raise the temperature. The normal temperature of this region, during the months of July to November, is also comparatively high for its latitude, while Bathurst has a comparatively low temperature. *San Diego* and *Sacramento,* in California (in 32° 43′ N. and in 38° 35′ N.), are situated on the eastern side of the center of action (the pressure maximum of the North Pacific) during the months July to November, and cold northwesterly wind[illegible] when increased by increase [illegible]perature. At

these stations there should consequently, as a rule, be a negative correlation, as Dr. Clayton has found.

Roswell, in New Mexico, has a more northerly position than San Diego, in 33° 24′ N., 104° 27′ W., far outside the tropical regions, but has nevertheless a positive correlation, though not much developed.

According to Buchan's charts [1889], the prevailing winds in this region during the months of July to October should be southerly or southeasterly, dependent on the Atlantic pressure maximum. A raising of this maximum, by increased solar activity, might therefore be expected to raise the temperature at Roswell. But the positive correlation thus produced cannot be expected to be well developed, as the station is situated between the two centers of action (the pressure maxima) of the North Pacific and the North Atlantic. A shift in these centers of action may easily reverse the winds at Roswell.

At *Mauritius,* situated in 20° 6′ S. inside the tropical region, the prevailing winds are southeasterly. An increased activity of the winds by an increased solar activity, ought therefore to lower the temperature; and we may expect to find a well developed negative correlation at this station, which is also the case.

San Isidro, Manila, in the Philippines, is situated in 15° 22′ N., 120° 53′ E. The prevailing winds during the months of July to September are southwesterly, during November, northeasterly, and during October, variable, according to Alexander Buchan's maps. Dr. Clayton finds a well-developed positive correlation for this station. But at *Hongkong,* situated on the continent at a comparatively short distance to the northwest (in 22° 18′ N., 114° 10′ E., the conditions are different. The prevailing winds during July and August are southeasterly, during September-October-November northeasterly. An increase of both these kinds of winds, by increased solar activity, may be expected to lower the temperature at Hongkong. The southeasterly winds are sea-winds which during the hot season bring colder air in over the continent, while the temperature will rise when there is no wind or light land breezes. The sea-winds are also moist and will consequently bring more cloudiness, which will lower the daily maximum temperatures with which Dr. Clayton operates. We should therefore expect to find a negative correlation at Hongkong during the months of July to November, which is also the case.

Entebbe in Uganda (Africa) is situated under the Equator, in 0° 5′ N. and 32° 28′ E. If Dr. Clayton were right in his views, we should expect a very well developed positive correlation at this station near the Equator, especially as there is little wind. Dr. Clayton's investigations give, however, a positive correlation which is less developed than in most other places. According to our view, this is easily understood, considering that during the months of July to November there are very variable winds in this region, and no special direction can be said to be prevailing.

At Haparanda, in 65° 50′ N. 24° 9′ E., the winds are variable during the months of July to November, and consequently Dr. Clayton's investigations give a very small and doubtful positive correlation for this station.

At *Stykkisholm* in Iceland, in 65° 5′ N. there are similar conditions, this station being situated near the Icelandic pressure minimum which may often change its position. Dr. Clayton's computations consequently give a very small (negative) correlation.

At *Jurjew* in Russia, in 58° 22′ N., and 26° 43′ E., the prevailing winds are westerly in July and August, and more southwesterly in September, October, and November; but none of these winds are very warm. The consequence is that Jurjew has only a very small, indistinct (positive) correlation.

Valdivia in Chile, in 39° 48′ S. and 73° 15′ W., is situated on the southeastern side of the South Pacific pressure maximum and should consequently have prevailing westerly and southwesterly winds. But during the months July and August the winds come chiefly from the northwest, according to Buchan's maps, while during the months September, October, and November they have a more southwesterly direction, and should consequently be comparatively cold. Dr. Clayton's investigations give accordingly a negative correlation at Valdivia, though slightly developed.

At *Merida*, Yucatan, in 20° 50′ [illegible]
winds are northeasterly or north [illegible]
November, and being sea-winds [illegible]
ing. Dr. Clayton's investigation [illegible]
developed negative correlation fo[illegible]

At *Suva*, Fiji Islands, in the [illegible]
178° 26′ E.) southeasterly winds [illegible]
of July to November. As these [illegible]
Clayton's investigations giv[illegible]
though not very well [illegible]

These examples may suffice to show that, as a general rule, it depends on the situation of a station, with regard to the centers of action of the atmosphere, whether the correlation factor of the station be positive or negative, *i. e.*, whether the temperature at the place varies in the same direction or in the opposite direction of the solar activity. This proves that the fluctuations in temperature at the earth's surface depend greatly on the changes in the circulation of the atmosphere, while the latter are affected more directly by the changes in solar activity.

According to what has been stated above the shape of the normal isothermal lines may be expected to demonstrate the distribution of the positive or negative correlation between fluctuations in solar activity and in terrestrial temperature.

In figure 98 we have drawn some isothermal lines showing the mean temperatures for August, September, and October, compiled from Buchan's maps [1889], and have also introduced the maximum values of the correlation coefficients computed by Dr. Clayton for his thirty stations.

This map shows clearly that the said correlation is *positive* where the shape of the isothermal lines indicates comparatively high normal temperatures (*e. g.*, at *Pilar* in Argentina, at *Zungeru* in Nigeria, at *Zomba* in South Africa, at *San Isidro,* Philippines, at *Jacobshavn* in Greenland, at *Dawson* in Alaska, at *Laurie Island* in 60° 44′ S., 44° 39′ W., nay, even at *St. Johns,* N. B., where the isothermal line has a small bend towards the north). But this correlation is *negative* where the shape of the isothermal lines indicates comparatively low normal temperatures (*e. g.*, at *Sacramento* and *San Diego* on the west coast of U. S. A., at *Chicago,* at *Bathurst* in Gambia, at *Punta Arenas,* on *Mauritius,* on the *Fiji Islands,* at *Hongkong*).

It should be kept in view that Dr. Clayton, taking it for granted that the fluctuations in temperature at the earth's surface, at least in the tropical regions, are directly affected by the fluctuations in solar radiation, has used for his investigations the *daily maximum temperatures* at the various stations.

The maximum temperatures depend very much on the cloudiness of the season, and do not give a trustworthy indication of the *mean* daily temperature, which it would be of importance to know when we wish to examine the effect of the circulation of the atmosphere. The mean daily temperatures would probably have shown still better agreement with the fluctuations in the solar radiation.

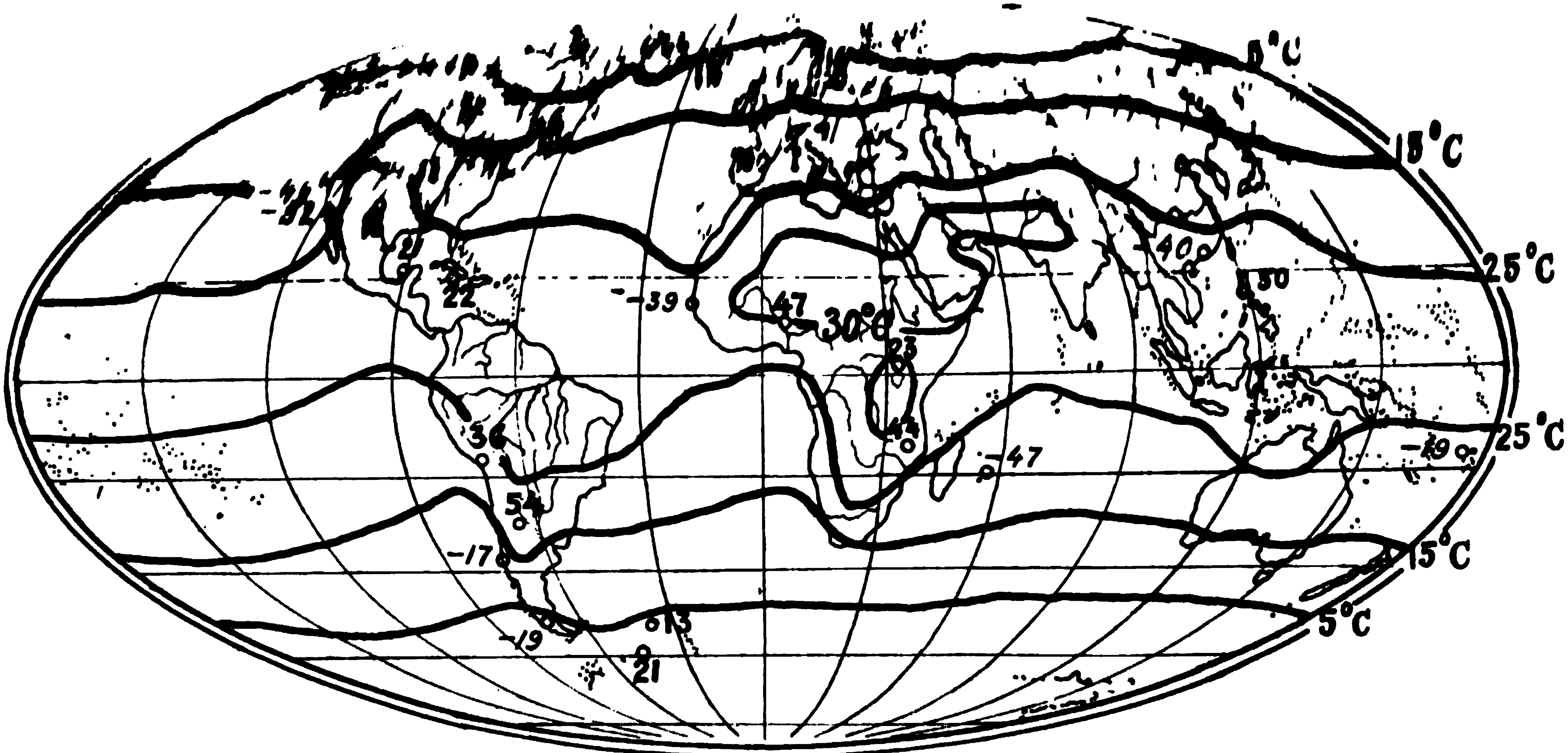

FIGURE 98. Isothermal lines showing the mean temperature (C°) of the globe for August, September, and October. The figures give the positive and negative values of the correlation factor found by Dr. Clayton for 30 stations in different regions of the globe, for July to November, 1913.

EFFECT OF THE SHORT-PERIOD VARIATIONS OF SOLAR RADIATION ON THE PRESSURE GRADIENT AND TEMPERATURE AT BERGEN, NORWAY

Dr. ABBOT has kindly given us the measurements of the "solar constant," made at Mount Wilson during the months of June to September, 1915, and June to October, 1916. The series of observations made during the year 1915 are especially good and complete. Most of the observations were made under very favorable circumstances, and may therefore be considered to be especially trustworthy.

We have compared the changes in the "solar constant" obtained during this year with the simultaneous meterological changes at *Bergen* on the west coast of Norway (60° 23′ N.). Having before found that the changes in temperature depend, to a very great extent, on the changes in the pressure gradient, we have first computed the changes in the latter by taking the difference between the air pressure at Christiania and the air pressure at Bergen at 8 o'clock every morning. We have then computed the consecutive seven-day means of the "solar constant" as well as of the pressure difference between Christiania and Bergen. When there were less than three measurements of the "solar constant" during seven days the values of the seven-day means were considered as doubtful. The correlation factor r for these two sets of seven-day means of the "solar constant" and the pressure difference was now computed by the following formula, worked out by Karl Pearson, and used by Dr. Clayton:

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}.$$

We then found the following values of the correlation factor:

CORRELATION OF SOLAR RADIATION WITH PRESSURE DIFFERENCE BETWEEN CHRISTIANIA AND BERGEN FROM CONSECUTIVE SEVEN-DAY MEANS, FOR THE PERIOD JUNE 8 TO SEPTEMBER 6, 1915.

Days following solar observations	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correlation Factor	.22	.33	.45	.55	.61	.63	.60	.57	.51	.38	.22	.07	−.08	−.21	−.30	−.35	−.38

These values of the correlation factor are comparatively high and amount to as much as 0.63 on the fifth day. This proves that there is a very well-developed positive correlation between the solar radiation and the pressure gradient between Christiania and Bergen. The maximum effect of the changes in the solar radiation follows five days later in the pressure difference. This correlation

factor found by us is considerably greater than those found for the correlation between the "solar constant" and the temperature at the various stations examined by Dr. Clayton.

We have also computed the seven-day means of the mean daily temperature at Bergen (taken with the thermograph). In figure 99 we have plotted the consecutive seven-day means of the "solar constant" as obtained at Mount Wilson (curve S) of the daily pressure difference between Christiania and Bergen (curve B) and of the mean daily temperature at Bergen (curve T), for the period from June to September, 1915.

FIGURE 99. Curves giving the 7-day means in June to September, 1915. cf: *S* the "solar constant"; *B* the pressure gradient between Bergen and Christiania; *T* the temperature at Bergen; *V* the variation of pressure from day to day at Bergen. The small letters along the curves indicate corresponding maxima and minima.

The agreement between these curves is very good. The maxima and minima of the pressure difference (marked by letters *a-n*) follow mostly some days after the corr
of the "solar constant" (marked b
corresponding maxima and minima
as a rule still a little later.

As it might give an indication
ological conditions we ha
day to day (at 8 a.

means of the values thus obtained in curve V of figure 99. This curve also shows a certain similarity to the curve S of the "solar constant," but the agreement is not as good as that of the other curves.

This analysis of the conditions in 1915 seems to prove that the daily changes in the "solar constant" cause changes in the distribution of pressure which in the region of Norway occur as a rule some days later. And the changes thus produced in the distribution of pressure cause changes in the temperature as a rule a day or two later. The probability is thus that by daily measurements of the

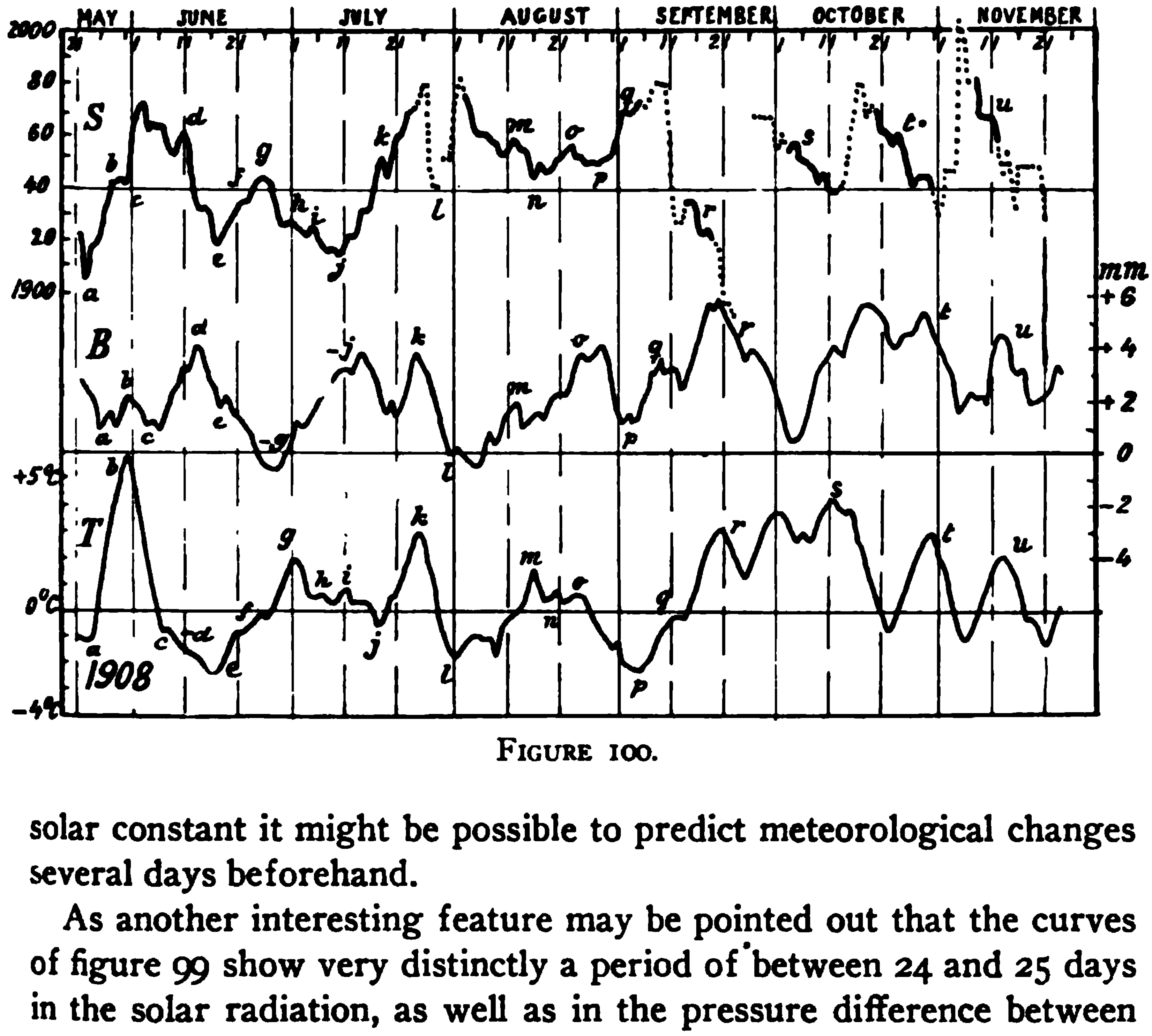

FIGURE 100.

solar constant it might be possible to predict meteorological changes several days beforehand.

As another interesting feature may be pointed out that the curves of figure 99 show very distinctly a period of between 24 and 25 days in the solar radiation, as well as in the pressure difference between Christiania and Bergen and in the temperature at Bergen. There are also indications of a shorter period of about 12 days, which is especially conspicuous in curve V, representing the barometric variability from day to day at Bergen.

For other years for which fairly complete series of observations of the "solar constant" were obtained at Mount Wilson, we have also computed the seven-day means of the "solar constant," of the simultaneous temperatures at Bergen and of the pressure difference

between Christiania and Bergen. We have plotted the values thus obtained in figures 100-106. The maxima and minima corresponding to each other in the different curves of the same year are marked with the same letters. Where a maximum has been reversed to a minimum or vice versa, the corresponding letter has a minus.

The curves marked *B* and *T* show that as a rule there is a fairly good agreement between the changes in pressure difference between Christiania and Bergen (*B*) and the changes in temperature at Bergen (*T*). In some cases—*e. g.*, in June till middle of July,

FIGURE 101.

1908, in October, 1908, about July 24 and November 7, 1909, in the beginning of June and July, 1910—the curves go, however, in opposite direction to each other. This might naturally be expected, considering that the pressure difference between Christiania and Bergen is not always a measure for the real barometric gradient at Bergen or in Norway as a whole.

The agreement between the curves *S* for the "solar constant," and the curves *B* and *T* for the pressure difference between Chris-

t

a

t

t

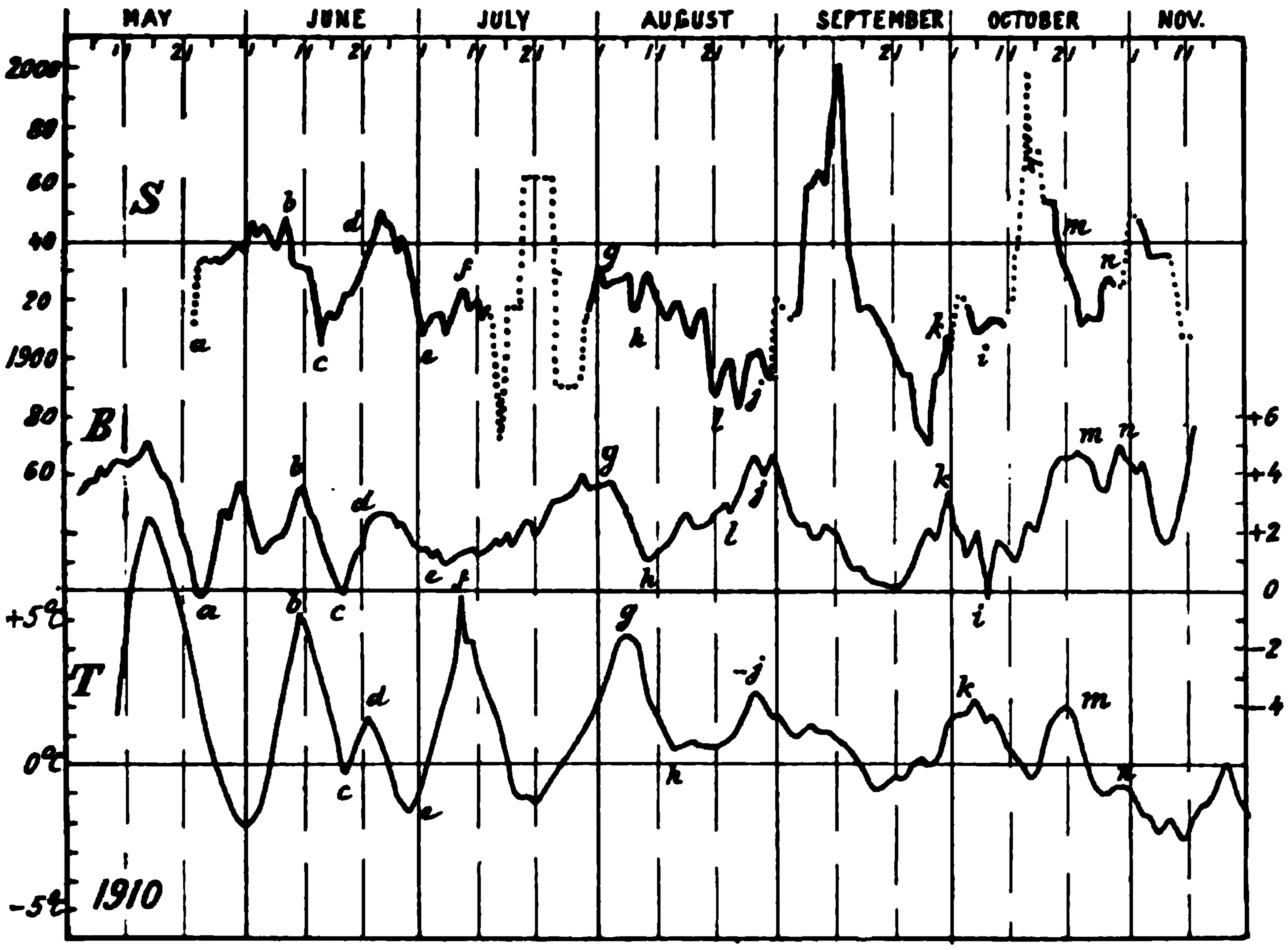

FIGURE 102.

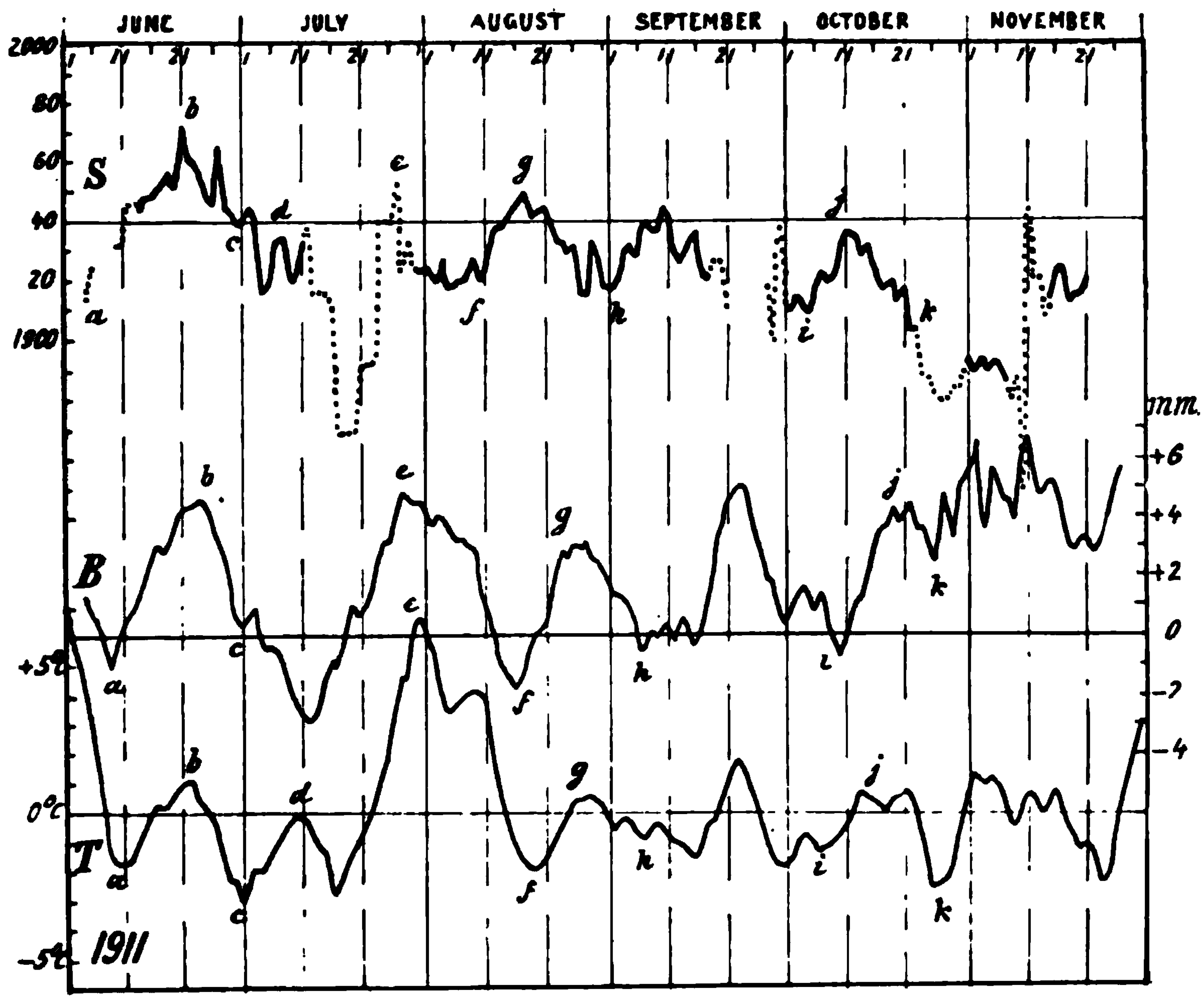

FIGURE 103.

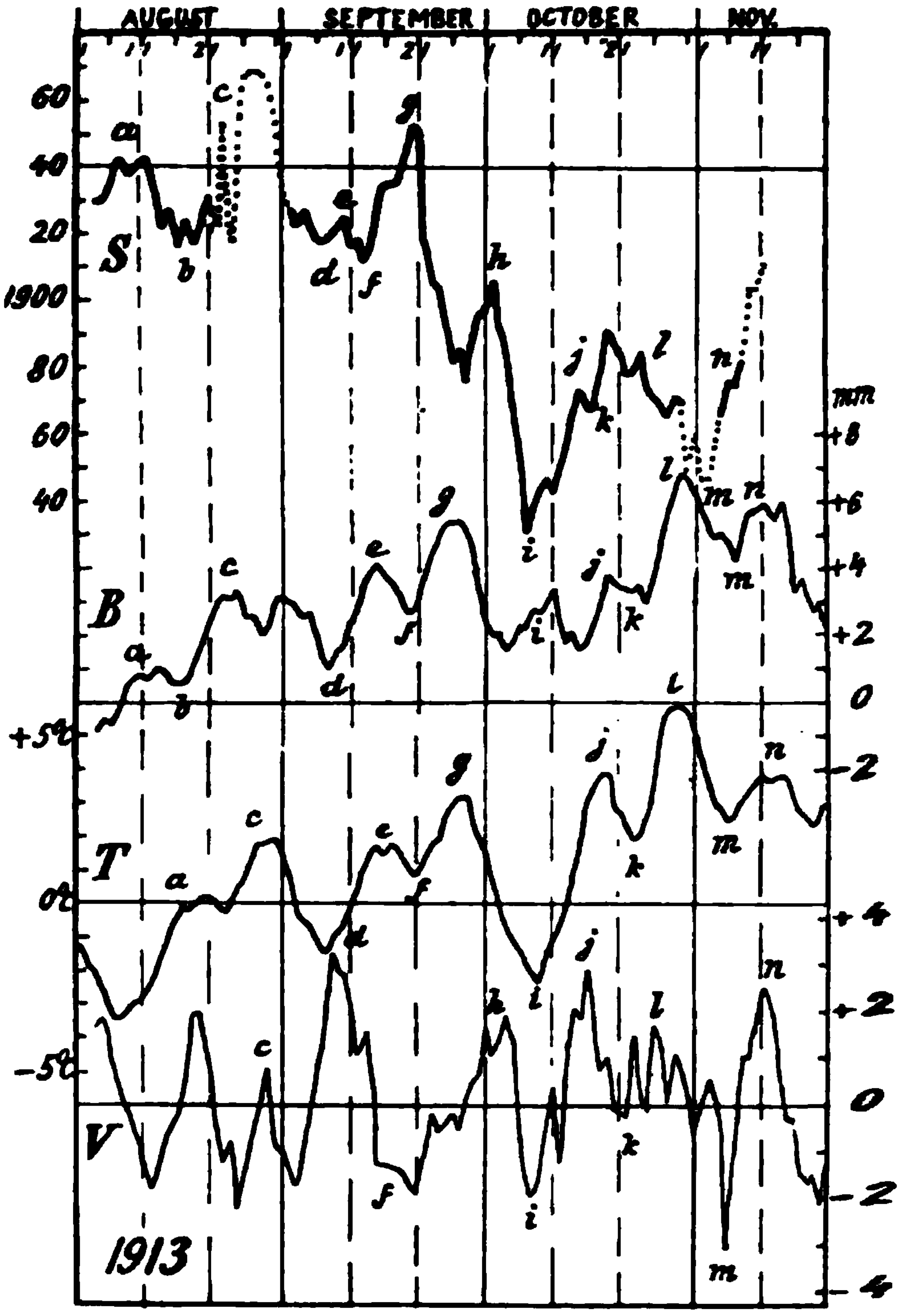

FIGURE 104.

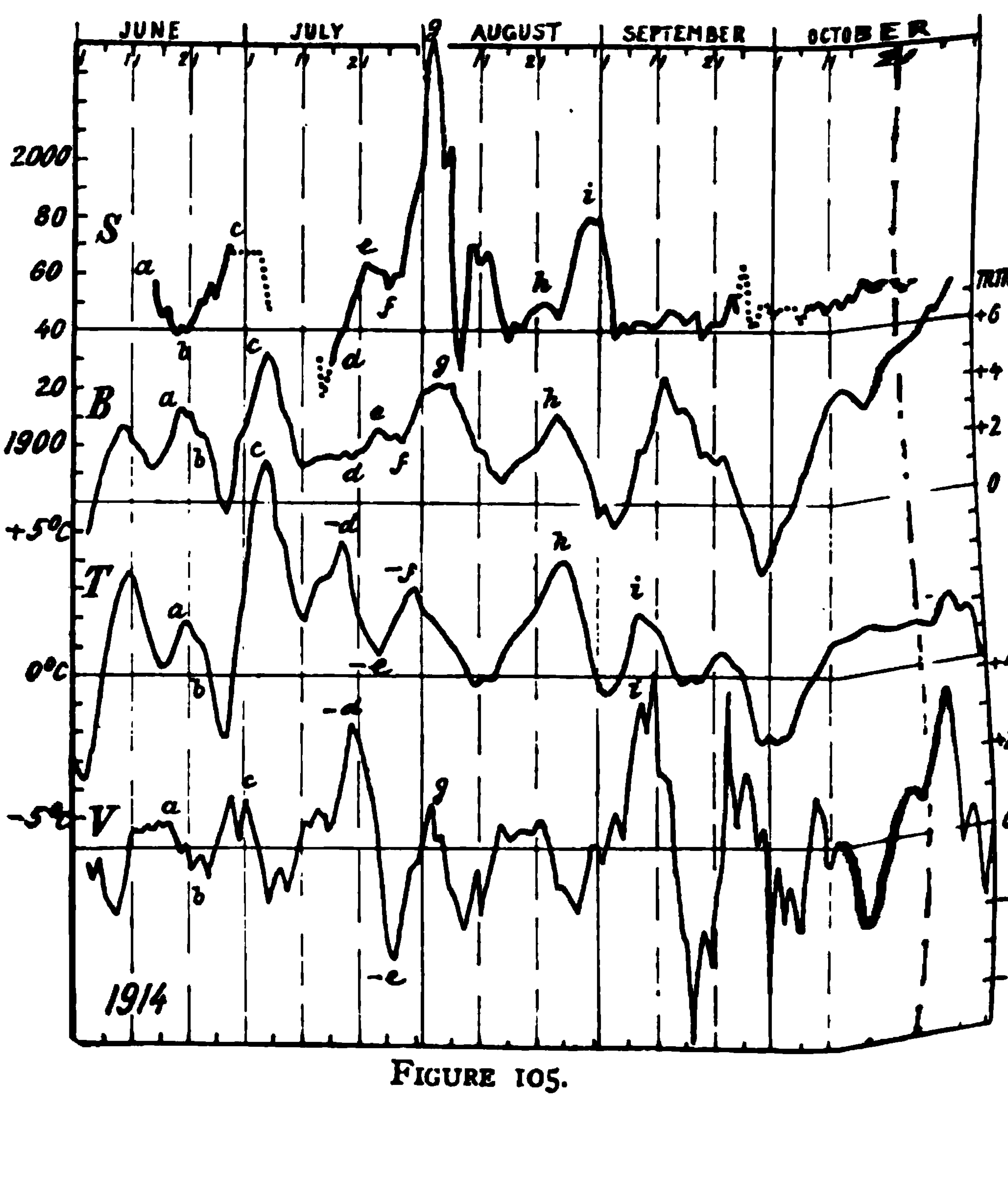

FIGURE 105.

ment with the two other curves is better than when the solar observations were less complete.

As a rule, the agreement between the solar curves (S), and the temperature curves (T), and the pressure curves (B) is direct, but in some cases it is also inverse. This seems, for instance, to some extent to have been the case with the pressure-difference (but partly not the temperature at Bergen) in June and partly July, 1908, with

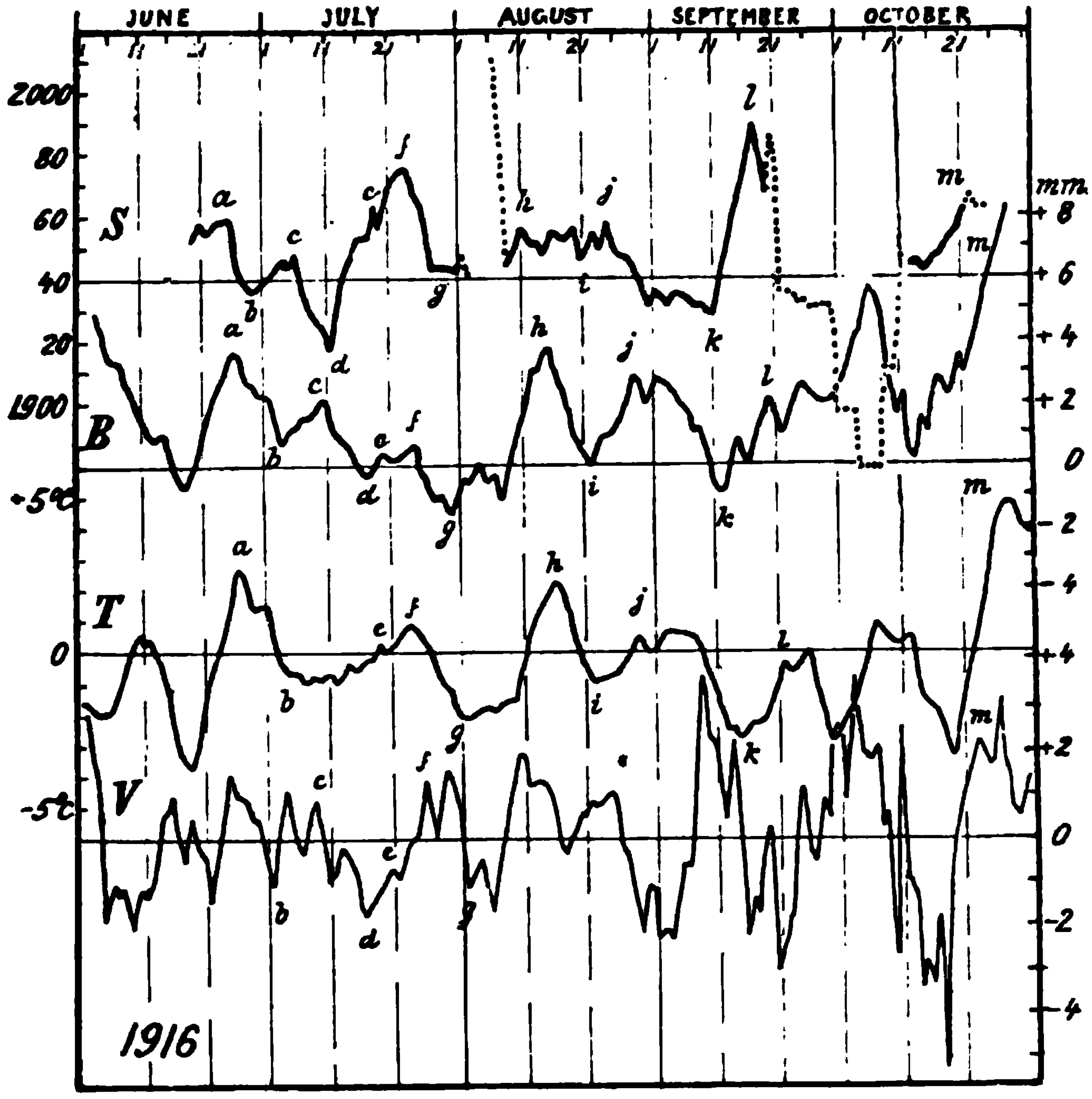

FIGURE 106.

FIGURES 100-106. Curves showing the 7-day means for the summer and fall of the year 1908, 1909, 1910, 1911, 1913, 1914, and 1916, of: S the "solar constant"; B the pressure gradient (mm.) between Bergen and Christiania; T the temperature at Bergen; V the variation of pressure (mm.) from day to day at Bergen.

The small letters of the curves indicate corresponding maxima and minima. A minus before the letter indicates inversion.

the pressure difference and partly temperature in July, 1909, in September, 1910, in July, 1914, provided that the obtained values for the "solar constant" may be considered as sufficiently trustworthy in these cases. It seems noteworthy that during 1913 the curve S for the "solar constant" is on the whole *descending*, with decreasing values, from August to October, while the curves T and B, for temperature as well as pressure difference, are on the whole *ascend-*

ing during this period, with increasing values. In September and October, 1909, the values of the "solar constant" seem likewise on the whole to have been decreasing while the values of pressure difference and temperature were on the whole increasing.

Most curves, the temperature and pressure curves as well as the solar curves, show indications of a period varying in length, mostly between 25 and 27 or 28 days, in most cases about 27 days. There are also frequent indications of a subdivision of this longer period into a shorter period of half the length.

The above results, that the pressure gradient as well as the temperature at Bergen vary, on the whole, directly as the solar radiation, agree with our earlier results obtained by a comparison between the monthly fluctuation in the relative numbers of sun spots, and the monthly fluctuations in the pressure gradient of the North Atlantic and in the temperature of Norway. We found (cf. fig. 92, curves III, IV, and V) that especially during the period 1903 to 1911, the fluctuations in the sun spots from month to month are as a rule repeated directly in the fluctuations of the pressure gradient, and of the temperature in Norway. The latter fluctuations occur often a short while after those of the sun spots. We also found that especially during the said period there was a conspicuous period of eight months in the fluctuations in sun spots as well as in the fluctuations in the pressure gradient and in the temperature of Norway (cf. fig. 92).

FLUCTUATIONS IN AIR PRESSURE AND SUN SPOTS STUDIED BY TWELVE-MONTH MEANS

We have continued our investigations, by means of consecutive twelve-month means, on the fluctuations in temperature and air pressure at stations in different regions of the globe.

We much regret that for very important high-pressure as well as low-pressure regions of our globe there are no satisfactory series of barometric observations at hand. We may especially mention the Pacific Ocean, the tropical low-pressure region of the Atlantic, the high-pressure region of the South Atlantic and the Indian Ocean, the antarctic low-pressure regions. It is therefore not possible, at present, to discuss the barometric fluctuations (at the earth's surface) of the atmosphere as a whole. We have been obliged to limit our investigations to a comparatively small portion of the globe's surface.

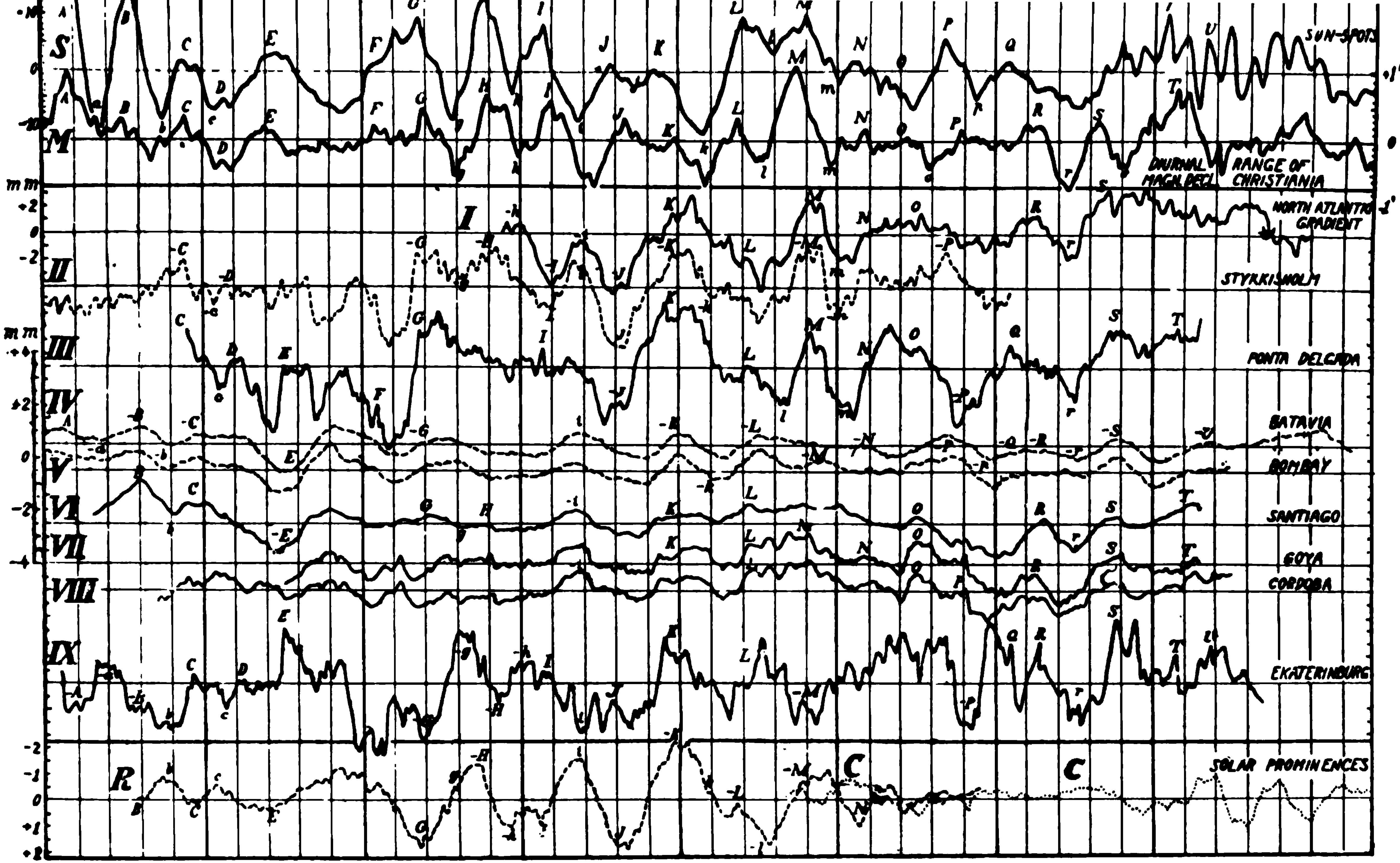

FIGURE 107. Curves *I-IX*, 12-month means of departures of air pressure (mm.). The departures are from normals that for the stations of curves IV to IX are computed for the thirty years of 1877 to 1906. *S* sun spots; *M* diurnal range of *magnetic declination at Christiania; R* and *C*, *solar prominences,* according to observations at the observatories of *Rome* (*R*) and of *Catania* (*C*). The values of curves *S, M, R* and *C* are obtained by substracting the 36-month means from the 12-month means. Curves drawn with broken lines are inverted. The letters along the curves indicate maxima (capitals) and minima (small letters). A minus before the letter indicates an inversion of the maxima or minima compared with those of the sun spots.

In figure 107 we have plotted the twelve-month means of the departures of the *air-pressure* at various stations. The unbroken curves are drawn directly, while the broken curves are inverted. The values are departures from normals; those for the stations of curves III-IX are computed for the thirty years from 1877 to 1906.

The curves of figure 107 show especially two very distinct types: the *North-Atlantic type* (curves I to III), and what we may call the *Indo-Maylayan South-American type* (curves IV-VIII).

The *North Atlantic type* of pressure curves is, in our figure, represented by curves I-III, from the low-pressure region (curve II for *Stykkisholm*, Iceland) and the high-pressure region (curve III for *Ponta Delgada*, the Azores) of the North Atlantic. In curve I is plotted the difference between the *Azores pressure maximum* and the *Icelandic pressure minimum* (cf. fig. 94, I). The vertical scale (in mm.) for curves I and II has been reduced to the half of that of curves III-IX. To the Atlantic curves I-III ought to be added the curve for the pressure difference between 30° N, 30° W and São Thiago, in the region of the NE. trade winds (see fig. 91, VIII).

All these curves have a striking resemblance to each other, the curve of the pressure maximum (III) agreeing very closely with the inverted curve of the pressure minimum (II). An increase of pressure in the region of the Azores pressure maximum consequently coincides as a rule with a decrease of pressure in the region of the Icelandic pressure minimum, and vice versa, as was already pointed out by Hildebrandsson [1897, etc.] and Hann [1904]. Hence the pressure gradients are simultaneously increased or decreased over the whole region of the North Atlantic (cf. fig. 91, VI, VIII; fig. 109, II, III).

Unfortunately we have had no opportunity of examining any sufficiently long series of barometric observations from stations inside the tropical low-pressure region of the Atlantic. Thus we do not know the nature of the barometric fluctuations in that region. But if we may judge from the observations at Port au Prince and

or the other of the two curves II or III (fig. 107) for these two regions, but no perfect resemblance to either of them, because they are neither maximum nor minimum curves (cf. the pressure curves for the United States of America, fig. 74, III, V, and perhaps also for the West Indies, fig. 71, VB, VIB). The typical curves only occur in or near the real centers of action.]

The *Indo-Malayan, South American type* of pressure curves, evidently characteristic for the *low-pressure region* of the *Indian Ocean,* and the high-pressure regions of the *South Atlantic* and the *South Pacific* Oceans, is represented by the inverted curves IV and V, figure 107, for Batavia and Bombay, and the direct curves VI, VII, and VIII for Santiago (Chile), Goya, and Cordoba (Argentina).

In figure 108 similar curves from different regions of the Indian Ocean and the western Pacific are reproduced. No curves have been inverted in this figure. These curves prove that the air pressure fluctuates in the same manner and almost simultaneously over the greater part of the regions surrounding the Indian Ocean, from India (curves 8 and 9) and the Philippines (curve 11) in the north to southern Australia in the south. The fluctuations seem as a rule to occur somewhat later in southern Australia than in India and the Malayan region (Batavia). The fluctuations are also considerably greater in Australia than in the tropics to the north. (cf. curves 13-15 and curve 12).

It is noteworthy that though southern Australia is situated inside the high-pressure belt of the southern hemisphere (the mean pressure of the year showing a local barometric maximum) still the pressure there does not fluctuate inversely as that of the tropical low-pressure belt to the north (Batavia, Bombay), but directly in the same manner.

The barometric fluctuations at Mauritius and Antananarivo (Madagascar), in the western Indian Ocean (curves 2 and 3) are of the same type as those of the northern and eastern Indian Ocean (cf. figs. 90 and 71) and of Australia as well as of the Philippines, but there are important dissimilarities as the curves 2 and 3 show. This may be due to the fact that these stations are near to another center of action.

We do not know what the barometric fluctuations may be in the region of the pressure maximum of the southern Indian Ocean; but curve 1 proves that at Cape Town situated in the high-pressure belt, between the pressure maximum of the Indian Ocean and that of the South Atlantic, the barometric fluctuations differ much from

FIGURE 108. Barometric curves smoothed by 12-month means: For 1, Capetown; 2, Antananarivo, Madagascar; 3, Mauritius; 4 and 5, Indian Ocean (cf. fig. 90); 6, Colombo, Ceylon; 7, Wellington, Southern India; 8, Hyderabad, India; 9, Bombay; 10, Rangoon; 11, Manila, Philippines; 12, Batavia; 13, Port Darwin, Northern Australia; 14, Adelaide; 15, Sydney, Australia; 16, Stykkisholm, Iceland

No curves are inverted.

those of the northern and eastern Indian Ocean, and are remarkably smaller. They may be a mixture between the latter fluctuations and the inverse fluctuations occurring in the high-pressure region of the South Atlantic to the west.

Curve 16, figure 108, giving the twelve-month means of the pressure at Stykkisholm, Iceland, shows that there is much direct similarity between the barometric fluctuations of the Icelandic pressure minimum and those of the Indo-Malayan low-pressure region, and the Australian high-pressure region, situated very nearly antipodically. But the fluctuation in the Icelandic region is very much greater. This may probably be due to the fact that the area of the Icelandic pressure minimum is very small as compared with that of the Indo-Malayan, Australian region.

If we go only short distances outside the area of the Icelandic minimum, *e. g., to* Aberdeen (Scotland), or to Norway, or to the west coast of Greenland the barometric fluctuations differ very much from those of Stykkisholm, and also from those of Ponta Delgada; the reason being that these regions are outside the centers of action and their fluctuations belong to a mixed type.

The pressure curves VI, VII, and VIII (fig. 107) for *Santiago* in Chile, *Goya* and *Cordoba* in Argentina, show great similarity to the *inverted* curves IV and V for Batavia and Bombay. This is in perfect accordance with what the two Lockyers have found, as we have mentioned in chapter X.

The three South American stations are in the high-pressure belt of the southern hemisphere between the maxima of the South Atlantic and the South Pacific. The curve of Santiago shows the most typical agreement with those of Batavia and Bombay, possibly because it is nearer to the center of action, the annual pressure maximum of the South Pacific, than the two Argentina stations are to that of the South Atlantic.

The two types of curves (*e. g.*, fig. 107, curve VI, and curves I-III; fig. 108, curve 16 and curves 2-15 show on the whole much similarity to each other, but also dissimilarities, *e. g.*, in the years 1877-78 (marked E), 1884-85, 1892-93, and partly 1894-95, though, *e. g.*, in 1894-96 the curve of Stykkisholm agrees remarkably well with those of southern Australia (cf. fig. 108, curves 14, 15, 16).

We have also made an analysis of the yearly barometric changes in Siberia where, however, the conditions differ greatly during the year, there being a high barometric maximum in southern central Siberia and in Mongolia, in the winter, but a minimum in the

summer. The winter maximum is, however, predominating, and taking the mean distribution of pressure during the whole year there is a barometric maximum over central Siberia and Mongolia, south of Lake Baikal.

The pressure curve for Ekaterinburg (fig. 107, IX) shows in most years more similarity to the pressure curve of Ponta Delgada than to the inverted curves for Batavia and Bombay.

It was mentioned in chapter X that according to Blanford's investigations the winter pressure in western Siberia and Russia changes inversely as the pressure in the Indo-Malayan area, while the summer pressure, especially at Ekaterinburg and Barnaul, varies greatly in the same direction.

In figure 109 we have given the barometric curves, smoothed by twelve-month means, for seven stations in different regions of Siberia and eastern Russia, east of the Ural mountains. The curves give the departures from normals computed for the thirty years from 1877 to 1906.

These curves show that the barometric changes are much the same over the greater part of eastern Russia and western Siberia. The curves from eastern Siberia, for Irkutsk and Nerchinskii (curves VI and VII) differ, however, somewhat from the others. The barometric curve for Irkutsk (fig. 109, VI) exhibits a remarkable and rather doubtful difference between the barometric values before and after 1887. The exceptionally great maximum in 1877-78 seems especially suspicious. It may, however, be noteworthy that at this time there was a striking disagreement between the Atlantic curves (Ponta Delgada, fig. 107, III) and the curves of the Indian Ocean and South America, as was mentioned before.

The total pressure of the atmosphere being constant, an increase of pressure in one region of the globe must be counterbalanced by a corresponding decrease in other regions. Our investigations seem to indicate a certain regularity in the barometric fluctuations in this way: that an increase of pressure in one high-pressure region coincides more or less with simultaneous increases in other high-pressure regions of the globe, and with simultaneous decreases of pressure in the low-pressure regions, and vice versa.

We have found that the barometric fluctuations of the *Icelandic pressure minimum* coincides as a rule not only with the barometric fluctuations of the low-pressure region of the Indian Ocean and the Indo-Malayan region, but also with those of Australia, where there is, to some extent, a high-pressure region.

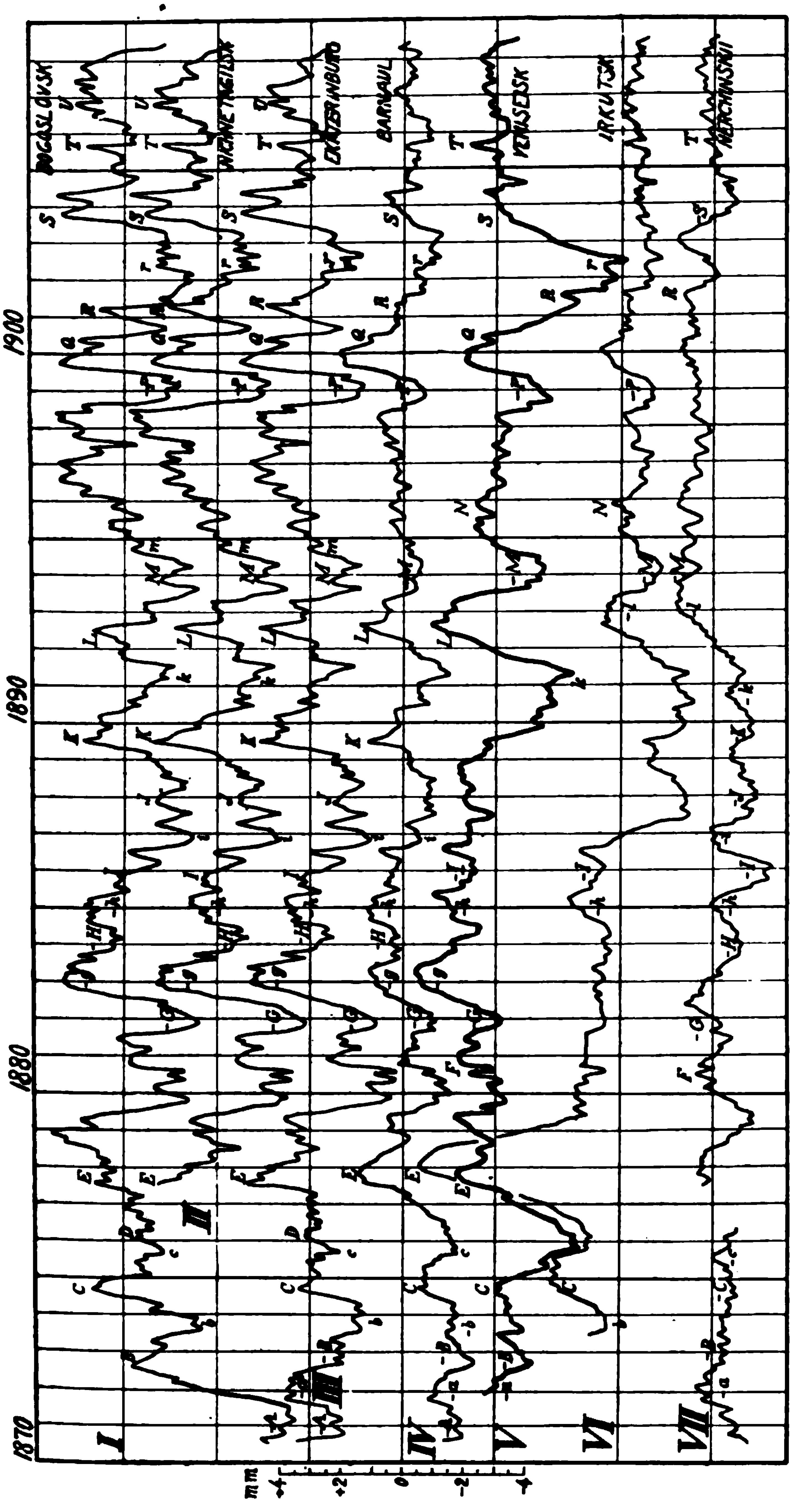

FIGURE 109. Barometric curves (I-VII) smoothed by 12-month means, for seven stations in eastern Russia (east of the Ural mountains), and in Siberia, viz.: Bogoslovsk (59° 45′ N., 60° 1′ E.), Nichne Tagilsk (57° 54′ N., 59° 56′ E.), Ekaterinburg (56° 50′ N., 60° 38′ E.), Barnaul (53° 20′ N., 83° 47′ E.), Yeniseisk (58° 27′ N., 92° 11′ E.), Irkutsk (52° 16′ N., 104° 19′ E.), Nerchinskii (51° 19′ N., 119° 37′ E.).

The barometric fluctuations of the *North Atlantic high-pressure region* (the Azores) coincide as a rule with similar fluctuations in the South American high-pressure region (probably also in that of the South Pacific and the South Atlantic) and to some extent also with the fluctuations in Siberia.

It has to be considered that the distribution of pressure, and the situation of maximum and minimum are subject to great alterations summer and winter in Asia as well as in the tropical regions of the Indian Ocean and the Indo-Malayan region; which is not the case in the Atlantic, in the Pacific, and also in the southern Indian Ocean. Hence we cannot expect the twelve-month means of the former regions to give full agreement with those of the latter regions.

The curves of figures 107 and 108 demonstrate clearly that the pressure changes are much smaller in the tropical regions than in higher latitudes of the northern hemisphere.[1] This may to some extent be due to the fact that the tropical low-pressure belt has more regular conditions and a much greater area than the pressure maxima and pressure minima of the northern hemisphere.

In the high-pressure belt of the southern hemisphere, the barometric changes at the South American stations (fig. 107, VI, VII, VIII) are greater than the fluctuations shown by the tropical curves (IV and V), but not as great as the fluctuations shown by the curves III and II for the pressure maximum (Ponta Delgada), and pressure minimum (Stykkisholm) of the North Atlantic. The explanation may be, on the one hand, that the high-pressure belt of the southern hemisphere is not as extensive as the low-pressure belt of the tropical regions, but on the other hand, the barometric conditions are more uniform in the southern hemisphere than they are in the northern hemisphere, where there is less ocean.

According to our earlier investigations we might expect that an increased solar activity would cause an increased circulation of the terrestrial atmosphere, raising the barometric maxima and lowering

If the daily number of *solar prominences* be taken as a measure of solar activity, we obtain the same result for the eleven-year period (cf. figs. 69 and 70). But in the shorter periods of a few years, the atmospheric circulation seems to fluctuate inversely as the number of prominences, according to the observations at the Roman observatory. This may be seen in figures 107 and 110, where the inverted curves R and V, respectively, represent the departures of the daily number of prominences observed at Rome (cf. also fig. 70, B and RC). The same thing was practically found by the two Lockyers [1902, 1904] and by Bigelow [1908], that, *e. g.*, the pressure of Bombay should fluctuate directly as the solar prominences, and the pressure at Cordoba inversely.

Upon closer examination of the curves in figures 107 and 110 we find, however, that the barometric variations demonstrated by these curves frequently occur earlier than the corresponding variations exhibited by the curve of prominences, and besides it is only the middle part of the inverted curve R, figure 107, between the years 1885 and 1895, that agrees with the barometric curves.

It has also to be considered that the observations of prominences made at Palermo and Catania differ much from the Roman observations.

It is the Roman observations that have been used by the Lockyers (and also chiefly by Bigelow)[1] and they have paid most attention to the above mentioned years where there seems to be a remarkable agreement between the curve of prominences and the barometric curves. This explains their unexpected results.

By special treatment of the relative numbers we have been able to demonstrate a few-years period in the *sun spots*, similar to those found by the Lockyers, and by Bigelow in the prominences. We consider it probable that the sun spots give a more trustworthy measure of the solar activity, especially as the variations of sun spots agree remarkably well with the variations in terrestrial magnetism, which is probably a sensitive measure of the changes in the amount of solar energy received by our globe.

The curves *S* and *M*, in figure 107, showing the fluctuations in sun spots and in the daily variations of the magnetic declination at Christiania, have been formed by plotting, on squared paper, the consecutive twelve-month means, from which have been subtracted

[1] As was mentioned before, Mr. Bigelow made, however, a serious mistake in his computations of the mean daily number of prominences, by not dividing the numbers observed in each month by the numbers of days of observation.

the thirty-six-month means, in order to eliminate the longer periods (cf. fig. 94, MK, fig. 96, I, III).

There is undoubtedly to a certain extent, an agreement between these two curves and the barometric curves I-IX (fig. 107) for high-pressure regions as well as low-pressure regions of our globe. In some years the maxima or minima of the solar and magnetic curves are found in all barometric curves I-IX (*e. g.*, the maxima *C, K, R, S*, the minima *b, r*), while in other years the maxima and minima of curves S and M are only found in some barometric curves (*e. g.*, the maxima *B, E, G, H, L, M, P*, etc).

It may be noticed that according to all these curves the barometric fluctuations occur always somewhat later, and often several months later, than the corresponding fluctuations in sun spots, and in magnetic declination at Christiania.

On the other hand it may also be noticed that some barometric fluctuations, especially the maximum of the high-pressure regions (fig. 107) and the minimum of the low-pressure regions (fig. 108) of 1878-79, and the minimum of the high-pressure regions and the maximum of the low-pressure regions of 1880-81, do not correspond to any similar fluctuations in sun spots and magnetic declination, as exhibited by our curves in figure 107, though there may possibly be some slight indications in curve M.

On the whole, however, figure 107 demonstrates that there is the same rhythm in the barometric fluctuations as in the fluctuations of sun spots and magnetic declination, and we may infer that an increase of solar activity causes on the average an increase of atmospheric circulation of our globe by raising the chief barometric maxima and lowering the chief minima.

FLUCTUATIONS IN TERRESTRIAL TEMPERATURES COMPARED WITH FLUCTUATIONS IN AIR PRESSURE AND SOLAR RADIATION STUDIED BY TWELVE-MONTH MEANS

According to the results of our investigations, as described before in this paper, the fluctuations in temperature at the earth's surface are chiefly due to fluctuations in the atmospheric circulation, which again are caused by variations in solar radiation. The nature of the changes of temperature at the various stations, whether positive or negative, depends on the situation of the station in relation to the barometric centers of action. In regions where an increased activity of the centers of action will cause more cooling winds. the effect will naturally be a lowering of temperature, and

vice versa (*e. g.*, in the regions of the NE trade winds outside northwestern Africa (cf. fig. 110, III, IV). But in regions where an increased activity of the barometric centers of action will produce more warm winds the effect will be higher temperatures, and vice versa (*e. g.*, in Norway).

Taking it generally, we may therefore expect that in regions where the normal annual temperature is comparatively high for its latitude (or at least higher than in neighboring regions) an increased atmospheric circulation should, as a rule, have a warming effect, while in regions where the normal annual temperature is lower than that of the latitude it should have a cooling effect.

In figure 111 we have given the temperature curves, smoothed by twelve-month means, for several stations from different regions of the globe. The broken curves are inverted, while the others are direct. The curves show departures from normals that for the stations of curves VIII-X are computed for the thirty years 1877-1906.

At the top of the figure we have reproduced the curves of the barometric departures, smoothed by twelve-months means, at *Batavia* (curve I, inverted) at Ponta Delgada (curve II), and for the difference between the pressure maximum (Azores) and the pressure minimum (Icelandic) of the North Atlantic (curve III).

In *Norway* there are prevailing southwesterly winds during the year, and the temperature is much higher than for any other region of corresponding latitudes. This is due to the warm oceanic current outside its coasts and to the prevailing winds. The fluctuations in the temperature of Norway (curve IV) agree remarkably well with the barometric variations at Ponta Delgada (curve II) as also with the variations of the pressure gradient of the North Atlantic (curve III, and with the inverse barometric variations at Stykkisholm (see figs. 91, 95, and 108), as also with the inverse variations of the pressure gradient in the region of the NE. trade winds (see fig. 110, I and III).

What a decisive influence the situation of a station, in relation to the barometric center of action, has on the nature of its temperature variations is demonstrated by the striking difference between the temperature variations at stations lying no farther apart than the Azores on the northern side of the Azores pressure maximum and Madeira on its southeastern side, as well as the Cape Verde Islands to the south of it. The temperature in the Azores (Angra and Ponta Delgada) fluctuate as a rule inversely as the temperature in

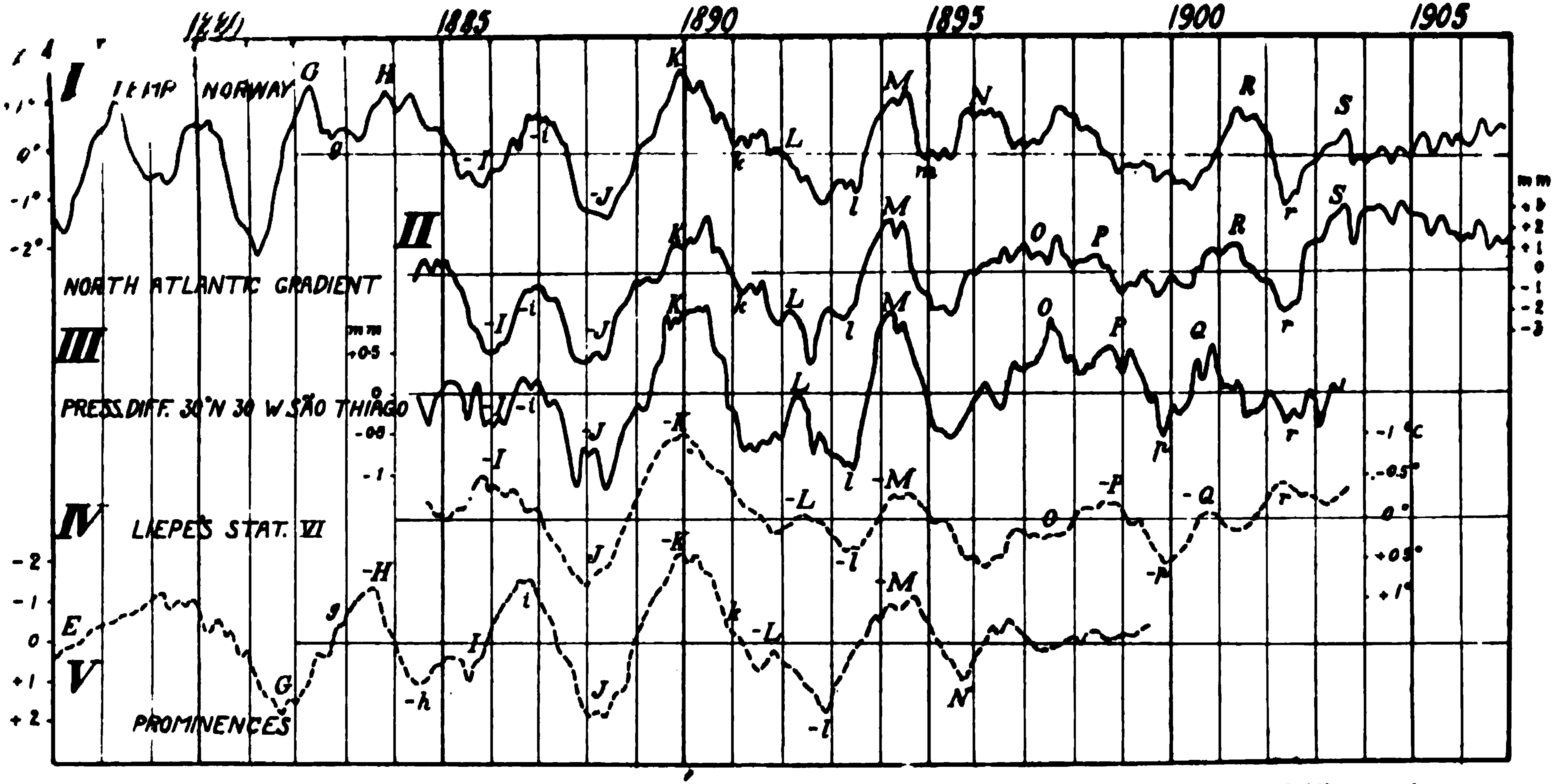

FIGURE 110. Twelve-month means of departures of: I. Temperature (C°) in the whole of Norway. II. Difference between the pressure maximum (Azores) and the pressure-minimum (Icelandic) of the North Atlantic (mm.). III. Difference between pressure (mm.) at 30° N., 30° W. and São Thiago. IV. Sea surface temperature (C°) at Liepe's station between 18° and 19° N., and between 21° and 22° W. (the curve is inverted). V. Solar prominences according to observations at Roman Observatory. Twelve-month means minus thirty-six-month means. The curve is inverted.

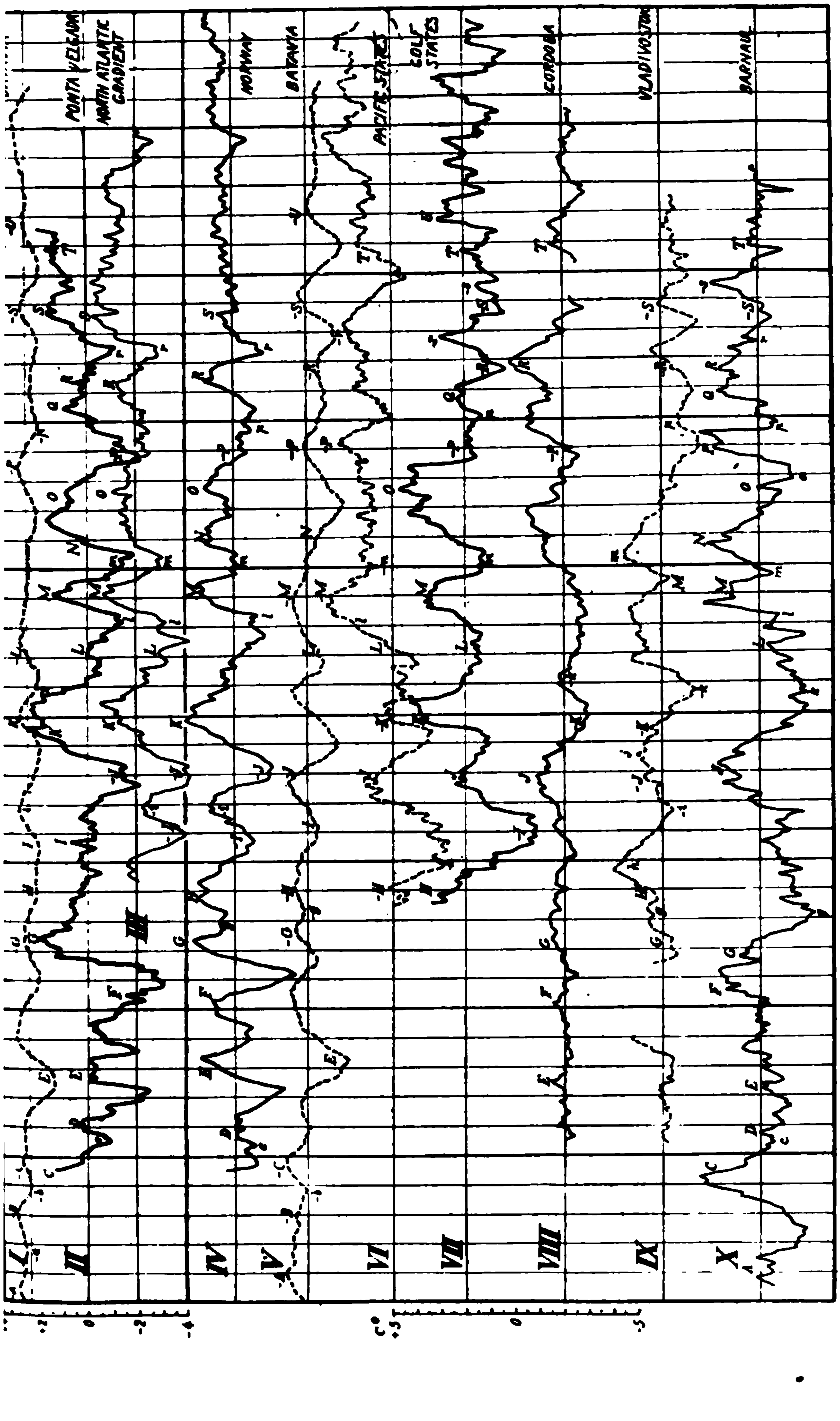

FIGURE III. Twelve-month means of departures of: I and II. Air pressure at Batavia (curves are inverted) and Ponta Delgada (Azores). III. Difference between pressure maximum (Azores) and pressure-minimum (Icelandic) in the North Atlantic. IV-X. Air temperature (C°) of the whole of Norway, at Batavia (Java), in the Pacific states (U. S. A.), at Cordoba (Argentina), Vladivostok (43° 7′ N., 131° 54′ E.), and Barnaul 53° 20′ N., 83° 47′ E.).

The curves drawn with broken lines are inverted. The departures are from normals that for Cordoba, Vladivostok, and Barnaul are computed for the thirty years 1877-1906.

Funchal (Madeira) and St. Vincents (Cape Verde Islands), see figure 112.

Batavia is in a tropical region where, owing to predominating oceanic influence, the mean annual temperature is comparatively low, and where an increase of atmospheric circulation (*i. e.*, a lowering of pressure) will generally lower the temperature. Hence the inverted curve V, in figure 111, for the temperature at Batavia agrees with the inverted curve I for the pressure at Batavia (cf. the inverse agreement between temperature at Batavia and pressure gradient of India, fig. 91, II, III) and also in some years with the direct curve II for the high-pressure region at Ponta Delgada.

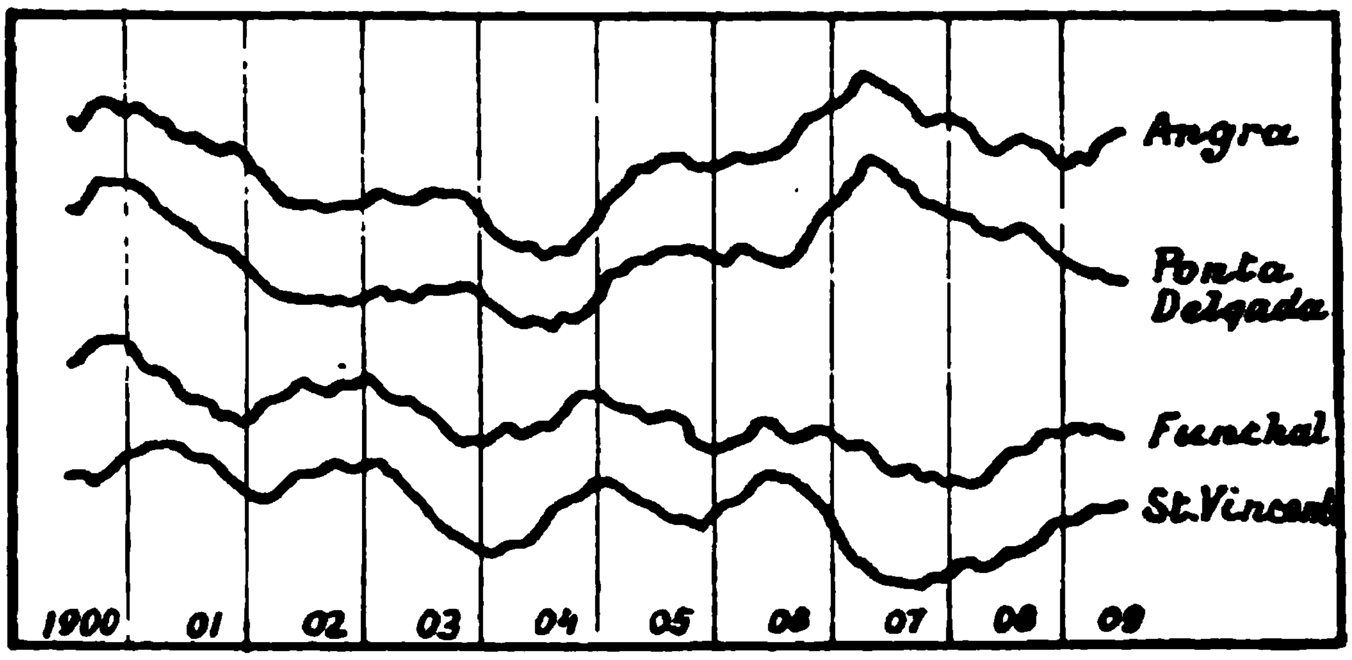

FIGURE 112. Temperature variations in the Azores, Madeira, and Cape Verde Islands. [Arctowski, 1914.]

Near the *Pacific Coast of the United States* the normal isothermal lines for the year turn sharply to the south for a distance of 20° of latitude or more, partly running almost parallel to the coast.

This region is to the east of the well developed barometric maximum of the North Pacific, and is under the predominating influence of this center of action, which has naturally a tendency to cause northerly, comparatively cold winds along the coast west of the mountains, as well as a cold sea current (with cold deep water lifted towards the sea-surface on its left-hand side) in the ocean outside. An increase of the activity of the center of action will therefore, as a rule, lower the temperature of the Pacific States, and vice versa. We consequently find that the *inverted* curve VI (fig. III) for the temperature of the Pacific states agrees on the whole well with the barometric curve II for Ponta Delgada, and the temperature-curve IV for Norway, as well as the inverted curves I and V for the pressure and temperature at Batavia.

It has, however, to be considered that immediately to the east of the Pacific States there is a comparatively very warm region in the western United States, where the normal isobaric lines for the year show comparatively low mean pressure, dividing between the North Atlantic high-pressure region to the east, and the North Pacific high-pressure region to the west. A shifting in the development and extension of these centers of action might easily invert the effects of the changes in atmospheric circulation in the temperature in these boundary regions. We may therefore expect that the agreement between the fluctuations in the temperature of the Pacific states, and the fluctuations of the barometric centers of action are sometimes inverted. This agrees with what we have already pointed out before (cf. fig. 75).

The region on the northern and northwestern side of the Mexican Gulf is chiefly under the influence of the North Atlantic high pressure center to the east, and an increase of the activity of this center may therefore, during a great part of the year, affect increased easterly and southeasterly winds with a rise of temperature, and vice versa. The temperature curve VII (fig. 111) for the Gulf states therefore show much similarity to the barometric curve II for Ponta Delgada, and with the inverted barometric curve I for Batavia. As, however, the Gulf states are in a barometric boundary region these agreements may sometimes be inverted as, for instance, in the years after 1901.

At *Cordoba,* in Argentina, the normal isothermal lines for the year go comparatively far south. This region has a comparatively warm climate, being situated to the west of the South Atlantic high-pressure center. A warm sea current is running southward outside the coast. An increase of the activity of the South Atlantic center of action may therefore be expected to increase the northeastern warm winds, and to raise the temperature. The temperature curve VIII (fig. 111) for Cordoba shows, on the whole, agreement with the barometric curve II for Ponta Delgada, and the inverted curve I for Batavia, but the maxima and minima occur often later at Cordoba than the corresponding maxima and minima in the other regions.

On the *east coast of Asia* the normal annual temperature is comparatively low, owing to the situation to the east of the barometric high-pressure center of inner Asia, causing much northerly wind along this coast, while western Siberia, to the west of the Asiatic high-pressure center, has much higher yearly temperatures, owing to more southerly winds. Changes in the activity of the Asiatic

[illegible] may therefore be expected to have opposite effects [illegible] temperature [illegible] the east and west [illegible] the [illegible]. The temperature [illegible] the inverted [illegible] fig. 111) and [illegible] show that this is to a great extent the case. [illegible] some agreement with the barometric curves [illegible] and with the other temperature [illegible]. [illegible] however, there are such great changes in the [illegible] during the year, there being a great minimum in the summer and a great maximum in the winter, [illegible] and as will be [illegible] horizontal circulation [illegible] for the thermal [illegible] pressure maxima in [illegible]

[illegible] temperature curves, smoothed by [illegible] regions of Siberia [illegible]. The values are departures [illegible]. The ex- [illegible] transition from [illegible] temperature fluctuations in [illegible] to those in western Siberia and eastern Russia [illegible] Ekaterinburg, [illegible] and [illegible].

[illegible] however, to be considered that the changes in temperature [illegible] may not depend [illegible] on the horizontal cir- [illegible] the atmosphere, but also to some extent on its vertical [illegible]. For instance, by a general increase of the atmospheric [illegible] there is a descending movement of the air, with an in- [illegible] pressure, in the high-pressure regions, and an ascending [illegible] the air, with a decrease of pressure, in the low-pres- [illegible] regions. According to the actual vertical distribution of tem- [illegible] the atmosphere, these vertical movements should have [illegible] raise the temperature in the high-pressure regions, [illegible] lower the temperature in the low-pressure regions, if it were [illegible] the effect of the horizontal air movements and also other [illegible] in some regions, which may go in the opposite direction.

The increase of pressure with descending air movements, in a [illegible]-pressure region will, on the other hand, give relatively calm [illegible] with a clear sky. During the winter in the temperate and [illegible] regions this will increase the radiation of heat from the earth.

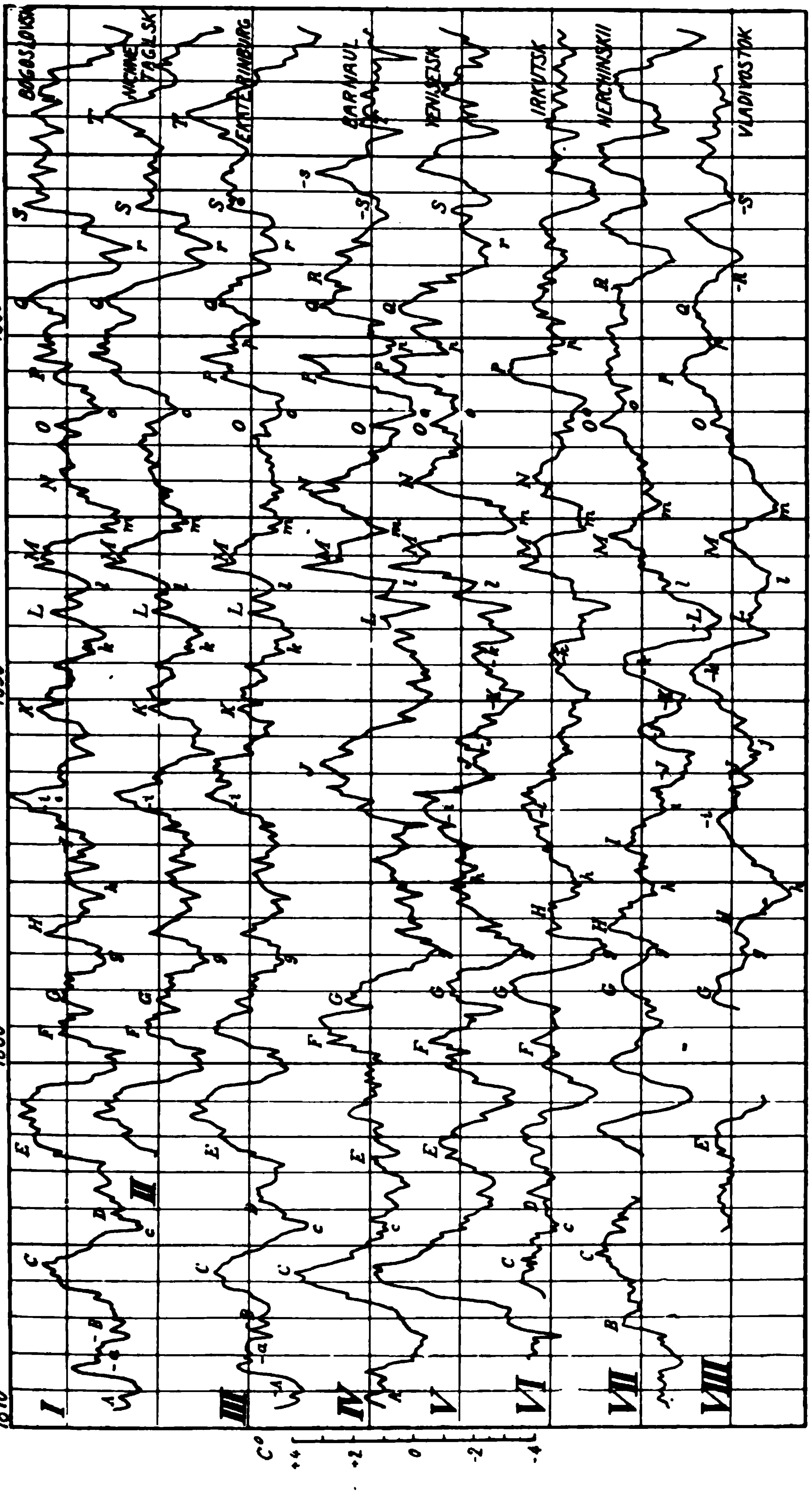

FIGURE 113. Twelve-month means of departure of the air temperature (C°) at eight stations in eastern Russia (east of the Ural mountains) and in Siberia (cf. fig. 109).

and will lower the temperature, while it may have an opposite effect in the tropical regions, where a clear sky with calm weather will raise the temperature, by increasing the effect of the insolation.

Hence we cannot expect to find any perfect agreement between the fluctuations in temperature and fluctuations in the barometric gradient, *i. e.*, in the horizontal atmospheric circulation, as there are various other conditions that influence the temperature at the earth's surface, especially in the regions of the barometric centers of action in higher latitudes.

We might expect the agreement between the fluctuations in horizontal circulation and in temperature to be more complete in regions lying between the barometric centers of action, than in regions near these centers. Our investigations also seem to prove that such is the case: *e. g.*, the variations in *temperature* in *Norway* show an almost complete agreement with the variations in the barometric gradient of the North Atlantic (and the variations in pressure at Ponta Delgada, and the inverse variations at Stykkisholm) while the variations in temperature in Iceland and the Azores show no good agreement with the barometric variations, neither one way nor the other.

As was pointed out before, it has also to be taken into consideration that the barometric centers of action may evidently shift their position or be divided, often for some length of time, and then the effect of the barometric changes on the temperature may in some regions be inverted during this period.

It is probable that changes in the sun's radiation may cause changes in the transparency of the terrestrial atmosphere, which again will affect the temperature in the various strata of the atmosphere, as well as at the earth's surface.

We have not here mentioned that changes in the sun's radiation of heat may naturally directly affect the temperature at the earth's surface, but these direct effects are evidently of subordinate importance as compared with the above mentioned indirect effects.

We have already pointed out as a mistake of most previous authors to suppose the temperature at the earth's surface to be a measure for the temperature of the terrestrial atmosphere, and consequently also for the variations in the quantity of heat received from the sun. It has to be considered that 40 per cent of the solar heat energy that reaches the outer layers of our atmosphere are reflected to space, and are absolutely of no account for the terrestrial temperature. Of the 60 per cent of the solar heat energy that

actually penetrates into our atmosphere, it is only about one third, or a little more than 20 per cent of the total solar heat energy, reaching our outer atmosphere, that penetrates to the earth and is absorbed directly to produce heat on its solid and liquid surfaces [cf. Abbot, 1917]. The rest of the 60 per cent of energy is absorbed in the atmosphere itself. Any change in the solar radiation of energy must consequently have a much greater effect on the atmosphere as a total, than at the surface of the earth.

The greater part of the solar energy received by our planet must naturally be absorbed in the *troposphere,* as it represents by far the greatest mass of the atmosphere.

It is this continuous supply of solar energy that creates the circulation of the atmosphere. Any change in this supply must consequently cause changes in the circulation. An increased supply of energy will naturally cause an increased circulation, and vice versa. The atmospheric circulation is due to differences in pressure, and changes in the circulation must consequently be due to changes in the distribution of pressure. At the earth's surface we may therefore expect to see the first effect of changes in solar radiation in the pressure, as we have really also seen in many cases (*e. g.*, at Batavia). The results of all our investigations seem to agree that the effect of the variations in solar radiation are first observed in the distribution of pressure, when the observations are made at the earth's surface.

The explanation is probably: Changes in the solar radiation cause temperature changes in the atmosphere, chiefly in the troposphere, and at heights that may possibly to some extent be determined by the cloud-formation.

The temperature changes in these layers of the atmosphere will cause movements of the air, which will also cause changes in the distribution of pressure at the earth's surface, and disturbances in the lower strata of the troposphere. An increased supply of energy will cause increased movement in the atmosphere, and this will again effect the temperature at the earth's surface, differently in the different regions, as we have mentioned before.

APPENDIX I

TEMPERATURE DEPARTURES FOR FORTY-SEVEN INLAND STATIONS, 1875-1910

COMMUNICATED BY C. G. ABBOT

DIRECTOR, SMITHSONIAN ASTROPHYSICAL OBSERVATORY

In Volume 2 of Annals of the Astrophysical Observatory of the Smithsonian Institution (Washington, 1908) an investigation of temperature departures was made with a view to see if notable anomalies occurred simultaneously and generally over the earth, such as might reasonably be ascribed to solar variations. At about the same time Professor Simon Newcomb published[1] an investigation with a similar aim. These investigations differed radically in method.

In the Smithsonian investigation care was taken to exclude coast and island stations, and to employ inland stations as uniformly distributed over the continents as the observational data allowed. Stations under oceanic influence or control, though their records were of longer standing and generally more accurate, were thought unsuitable, because the temperature effects of short interval solar changes, if such there are, would be greatly reduced at such stations. Furthermore, being unequally retarded, they would be non-synchronous, so that in a general mean they might altogether disappear. Ordinary graphical methods of exposing the results were employed. The stations were combined in groups according to location. Average departures and probable errors for these groups were computed in the usual way. The group results were combined into a grand average and probable error, and all these results were plotted as functions of time, from 1875 to 1905.

In Professor Newcomb's work the stations employed were mostly of an island or coast character. To illustrate how thoroughly some were under oceanic control, among them was Apia, Samoa, where the seasonal change from winter to summer ranges but 1°.1 centigrade, as compared with 14°.2 at Timbuktu and generally about 6° range at most inland stations where equal yearly changes of insolation outside the atmosphere occur. In his discussion Professor Newcomb devised and employed a very ingenious mathemati-

[1] Trans. Amer. Phil. Soc. Philadelphia, Vol. 21, 1908.

cal method of correlation, which though somewhat tedious, gave results wholly free from personal bias. The method answered the question: Does a coincidence of departures from normal temperatures, indicating a common cause, appear from the records of the investigated stations? His method did not indicate for non-periodic changes, *when* such changes took place, or how *great* their magnitudes.

Some of the conclusions from these two investigations were as follows:

Smithsonian	Newcomb
1. Higher temperatures prevail at sun spot minimum.	1. Higher temperatures prevail at sun spot minimum.
2. An increase of 100 Wolf. numbers is attended by about 1° C. decrease ot temperature.	2. Average sun spot maxima since 1840 have been attended by about 0°.26 decrease of temperature.
3. Indications of wide-spread coincidental short interval temperature fluctuations, reasonably attributable to solar variations, are found, but not without conflicting evidence.	3. "Apart from this regular fluctuation with the solar spots, and this possible more or less irregular fluctuation in a period of a few years, *the sun's radiation is subject to no change sufficient to produce any measurable effect upon terrestrial temperatures.*"

Since these results were published, short interval irregular solar variation of several per cent range has been established. The variability of the sun is now confirmed[1] by (a) Mount Wilson, California, observations of the "solar constant," (b) comparison of Mount Wilson and Bassour, Algeria, observations, (c) comparison of Mount Wilson and Arequipa, Peru, observations, (d) comparison of Mount Wilson and magnetic observations, (e) comparison of Mount Wilson "solar-constant" work with Mount Wilson "solar-contrast" work. The cumulative effect of this evidence is overwhelming. Besides this it has been shown by H. H. Clayton that correlations exist between fluctuations of solar radiation and changes of terrestrial temperature and pressure. These correlations are positive for some stations, but negative for others, and almost lacking at still others. This explains at once why such investigations as those we have been discussing could not with certainty exhibit strong evidences of short interval solar variability. Owing to complexities not yet understood, brief intervals of higher solar

[1] See Annals of the Smithsonian Astrophysical Observatory, 3; Smithsonian Miscellaneous Collections, 65, Nos. 4 and 9; and 66, No. 5; Terrestrial Magnetism and Atmospheric Electricity, 20, 143, 1915.

[2] Smithsonian Misc. Coll. Vol. 68, No. 3, 1917.

radiation produce increased temperatures at some stations, but decreased temperature at others, and at some stations little temperature change at all.

Hence it is necessary to treat the subject more in detail. Individual stations must be studied by themselves. In order to aid those who wish to undertake such investigations it seems worth while to publish *in extenso* the temperature departures found for the 47 stations employed in the Smithsonian publication of 1908. These were collected from the Library of the United States Weather Bureau, and much aid was furnished by the officials there, especially by Professor Kimball and Professor Talman, in the selection and collection of the data.

We give below the temperature departures from normals as published officially, or as computed by us from available data. The latitudes, longitudes, altitudes, and normal temperatures of each station are given at the head of each table. Monthly departures, computed from all available data extend generally over the time interval 1875 to 1910. As we explained in Volume II of the Annals, after departures from "mean" temperatures had been obtained for many stations in Asia and Europe, difficulty in computing "mean" temperatures was encountered in many instances. This led us at the time to employ "maximum" temperatures for many stations, as being more independent of changes in hours of observing. But we now regret that we did not employ means of "maximum" and "minimum" temperatures where "mean" temperatures were inconvenient. Although this would have increased the work of taking departures, the function is one which is less dependent on cloudiness than "maximum" temperatures, and more representative of temperature conditions. The footnotes indicate the conditions as regards latitude, longitude, and normals, whether north or south, east or west, "mean" or "maximum," Centigrade or Fahrenheit.

TEMPERATURE DEPARTURES FROM NORMALS—JANUARY

Station....	1 Cordoba	2 Albany	3 Pittsburg	4 Atlanta	5 St. Louis	6 La Crosse	7 Shreveport	8 Yankton	9 Dodge	10 Bismarck	11 Cheyenne	12 El Paso
tude .. ° ′	31 25	42 39	40 32	33 45	38 38	43 49	32 30	42 54	37 45	46 47	41 08	31 47
gitude. ° ′	64 12	73 45	80 02	84 23	90 12	91 15	93 40	97 28	100 00	100 38	104 48	106 30
ation .	439	30	231	371	219	208	73	375	772	510	1863	1158
nal ...	22°.9 C	31° F	38°	50°	40°	24°	55°	26°	40°	17°	36°	58°
[illegible]	+0.4	−9	−7	...	−9	−10	−7	−14	−18	−17	−11	...
6	−1.4	+7	+9	...	+11	+7	+8	+7	+12	+4	+1	...
7	+1.4	−6	−3	...	0	−3	−1	−1	−4	+1	+1	...
8	−1.7	0	+1	...	+2	+10	0	+6	+3	+12	+1	...
9	−0.6	−3	−4	+3	−4	+3	−2	+1	−7	+4	0	...
80	+0.5	+7	+14	+12	+16	+17	+14	+17	+11	+10	+5	+4
1	−1.8	−4	−3	−3	−10	−6	−8	−9	−9	−7	−3	−3
2	+0.6	+3	+2	+6	+1	+8	+2	+9	+2	+7	+1	−1
3	+0.8	−2	−2	+1	−8	−10	−3	−8	−6	−8	−4	−1
4	+2.1	±0	−5	−5	−5	−4	−6	+1	−3	−3	−2	−2
5	+1.1	0	−1	−2	−9	−7	−5	−9	−13	−8	−2	−1
6	+1.1	−2	−3	−6	−5	−4	−7	−11	−15	−9	−4	−3
7	+0.6	+1	+2	−1	+1	−3	+3	−6	+1	−8	...	+2
8	+3.1	−8	−2	+3	−6	−12	−2	−11	−3	−13	0	+1
9	−0.9	+7	+5	+1	+2	+4	+1	+4	+1	+8	0	−6
90	−1.0	+7	+12	+9	+7	+1	+9	−6	−2	−10	+1	+3
1	−1.0	+1	+2	0	+3	+9	−3	+11	−2	+17	−1	−6
2	−0.6	−1	−4	−4	−7	−1	−5	−3	+1	−1	−1	−3
3	−0.6	−7	−10	−6	−7	−10	+1	−2	+7	−3	+6	+2
4	+0.2	+3	+7	+4	+3	+2	+5	−4	+5	−6	0	−2
5	−1.9	−1	−3	−2	−6	−4	−3	...	−3	−9	−2	−1
6	−0.4	−4	−1	−1	+2	+3	−1	...	+8	−1	+7	+3
7	−0.7	+1	−4	−4	−3	−2	−3	...	−2	−3	−1	−5
8	+0.6	+1	+4	+4	+4	+6	+6	+10	0	+13	0	−3
9	+0.2	+1	+1	0	+1	+2	+1	+8	+5	+2	0	+1
1900	+3.4	+4	+4	+1	+5	+5	+1	+12	+10	+14	+8	+4
1	−0.3	+1	+1	+2	+5	+4	+5	+10	+9	−12	+5	+2
2	+2.5	−1	−1	−1	−1	+4	−1	...	+4	−7	+1	+3
3	−0.4	+1	0	−2	+1	+2	0	−5	+7	+8	+4	0
4	−1.4	−7	−5	−3	−4	−6	0	−1	+4	−3	0	0
5	−1.0	−3	−4	−6	−8	−6	−7	−6	−9	−6	−3	+1
6	−0.3	+8	+8	+2	+5	+8	+3	+10	+11	+5	+8	−3
7	+1.6	0	+6	+10	+5	−2	+11	−4	+3	−11	+3	+5
8	0.0	+3	0	−1	+2	+7	+2	+8	+10	+17	+3	0
9	+2.2	+3	+5	+4	0	+2	+5	+2	+2	−1	+6	+6
1910	+0.2	+2	0	+1	0	+2	+5	0	+2	+4	+1	+1

Station....	13 Salt Lake	14 Helena	15 Yuma	16 Carson	17 Bourke	18 Deniliquin	19 Clare	20 Alice Springs	21 Daly Waters	22 York	23 Bloemfontein	24 Graaf Reinet
tude .. ° ′	40 46	46 34	32 45	39 10	30 03	35 32	33 50	23 38	16 16	31 53	29 06	32 16
gitude. ° ′	111 54	112 04	114 36	119 46	145 58	145 02	138 37	133 37	132 23	116 47	26 13	24 32
ation .	1344	1256	43	1439	139	82	412	587	213	175	1377	751
nal ...	36°	28°	66°	44°	100°.2	94°.9	84°.3	98°.7	99°.2	77°.6	85°.9	88°.3
[illegible]	+2	...	...	...	...	+4.6	...	...	...	...	...	...
6	+2	...	...	...	...	−12.3	...	...	...	...	...	...
7	0	...	...	...	...	0.0	...	...	...	...	...	...
8	+3	...	...	...	+7.1	+6.9	...	...	...	...	...	...
9	+1	...	−1	...	+2.4	+4.8	...	...	...	...	−4.1	...
80	0	...	+1	...	−0.4	+1.4	+6.3	−2.6	...	+4.8	−3.0	...
1	+2	−11	0	...	−1.9	−3.7	−1.5	+5.5	...	−3.2	−3.5	−1.8
2	−5	−2	−5	...	+3.4	+0.8	+1.4	−1.8	...	0.0	+3.8	+1.6
3	−4	−2	−2	...	+0.5	−1.0	+0.5	+3.4	...	−1.0	−2.8	−2.2
4	0	−3	0	...	+4.4	−5.2	+1.1	+3.5	...	—	+1.1	−0.3
5	−1	+2	−3	...	+1.9	+0.6	−0.3	−0.6	+0.1	−1.9	+3.2	+0.7
6	+1	−7	−1	...	+2.8	+4.6	+2.1	+3.8	−0.6	—	−0.7	+0.1
7	+5	+3	+2	...	+3.4	+7.6	+5.1	+6.6	+2.9	−2.6	+2.2	−3.6
8	−4	−10	−3	−6	+2.3	+1.7	+3.3	+4.7	−6.9	+0.8	−3.1	−2.7
9	−6	−1	−2	−1	+3.7	+0.8	−0.1	−2.2	+0.3	−1.4	+3.5	−1.1
90	−3	−13	−3	−12	−3.3	+8.1	+5.4	−0.8	−1.4	+1.1	+3.8	−4.4
1	−1	+6	0	+1	−5.4	−5.7	−2.3	−3.8	+2.8	−2.5	−3.1	−1.8
2	−4	0	+2	+1	+1.8	−2.5	−2.5	+3.1	+6.3	+0.4	+6.9	+2.6
3	0	0	+8	+3	−1.2	−0.6	−1.1	+1.7	+3.2	+0.2	−1.4	+3.7
4	0	−2	−1	−1	−1.6	+4.2	+1.6	−4.3	−3.0	+0.2	−1.2	+2.1
5	+1	−3	−1	−4	−4.8	−5.3	−5.2	−10.2	−5.5	−2.6	+1.5	+2.3
6	+6	+4	+6	+7	+9.8	+3.8	+0.8	+1.6	−1.9	+4.0	+2.5	+2.1
7	0	0	−1	0	−2.4	−3.7	−4.3	+0.7	−0.1	+2.8	−4.8	+3.2
8	−7	+2	−5	−6	−0.8	+4.6	+4.0	+2.1	+1.0	+3.2	−2.4	−0.7
9	+4	+2	+2	+4	−2.7	−11.7	−9.1	−7.9	−6.2	−2.0	+1.4	...
1900	+7	+10	+8	+7	−2.1	−2.1	−1.7	−1.1	+2.8	+4.7	...	...
1	+5	+3	+2	+1	−1.3	−6.5	−2.0	−0.2	+6.4	+0.6	...	0.0
2	−3	+2	+2	0	+1.2	−3.4	−1.2	+0.7	−0.5	−3.4	...	−2.7
3	+3	+9	+3	+4	...	...	−1.6	−4.1	−0.4	+1.5	+3.3	+3.5
4	−2	+9	+2	+1	...	...	−4.9	−8.5	−6.0	−2.4	−4.3	...
5	+4	+1	+4	+6	...	...	+1.7	+0.3	+1.9	−4.0	+1.7	...
6	−1	+8	+1	—	...	...	...	...	...	+1.3	+2.4	...
7	+1	−12	−1	—	...	...	...	...	...	...	...	...
8	+2	+7	+3	—	...	...	...	...	...	−3.1	...	−0.4
9	+10	−7	+5	—	...	...	...	...	...	...	...	...
1910	0	0	0	—	−4.9	...	+2.6	−0.2	−1.6	−0.6	...	...

Stations 2-16 inclusive, Lat. N.; others, Lat. S. Stations 1-16 inclusive, Long. W.; others, Long. E. Station 1, C°; others, F°.
Stations 1 and 22 departures from normals of mean temperature, others, from normals of maximum temperature.

Station....	25 Sibsagar	26 Benares	27 Nagpur	28 Bellary	29 Lahore	30 Dera Ismail Kahn	31 Nerchinskii	32 Pekin	33 Irkutsk	34 Barnaul	35 Tashkent	36 Irgiz
	° ′	° ′	° ′	° ′	° ′	•° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude ..	26 59	25 19	21 9	15 9	31 34	31 51	51 19	39 57	52 16	53 20	41 20	48 37
Longitude.	94 41	83 3	79 9	76 57	74 20	70 56	119 37	116 28	104 19	83 47	69 18	61 16
Elevation .	101	81	311	443	214	180	621	38	467	163	478	112
Normal ...	69°.5	74°.8	83°.5	88°.0	67°.0	68°.4	−29°.4	−4°.6	−20°.1	−19°.3	−1°.3	−15°.4
Year												
1875	−3.1	+0.5	−1.6	+0.1	+5.9	+3.4	+0.9	...	...	...	...	...
6	−1.0	+2.0	+1.6	+0.8	0.0	−0.7	+3.2	−0.7	−2.1	0.0	−3.7	−3.0
7	+1.8	−1.9	−2.9	0.0	−1.9	−2.5	−1.2	−1.3	−10.5	−0.8	+0.6	−2.3
8	+0.2	−3.4	+0.7	+1.0	−2.8	−2.8	+0.8	−2.6	−7.0	−2.5	−1.0	−2.6
9	+3.1	+3.7	+1.4	−0.1	+6.5	+4.8	−1.8	−0.3	−4.8	−0.1	+3.3	−2.9
80	+2.5	+1.7	+0.7	—	+5.2	+4.9	+0.2	−2.2	−6.3	−2.5	+0.4	−4.1
1	+2.7	+1.0	−0.3	−1.3	+5.0	+5.4	+0.9	+0.3	+3.9	+9.4	+9.5	+4.8
2	+1.8	+3.4	+2.6	+2.1	+1.0	+3.4	+3.0	+1.8	+4.7	+5.0	−2.3	+2.2
3	−0.1	−0.6	−0.7	−2.1	+0.6	+0.3	+1.6	0.0	−0.1	+1.6	−2.4	−3.1
4	+0.8	+1.2	−3.2	−3.5	+2.9	+3.0	+3.3	+1.0	+2.7	+4.6	+3.1	+1.6
5	−1.1	−0.5	−0.1	+0.5	−3.5	−3.3	+1.9	...	...	−0.4	−3.8	−1.9
6	−0.7	−0.8	−2.4	−1.4	−3.2	−2.3	...	...	+1.4	+4.7	+1.2	0.0
7	−3.6	−3.4	+0.3	+0.6	−3.3	−2.7	−3.5	...	−4.6	−2.9	...	−3.2
8	−1.5	−4.9	−5.1	−1.2	−1.5	−1.9	+1.2	...	−1.7	+2.8	...	+6.5
9	+1.7	—	+4.0	+1.1	+2.0	—	−3.8	...	−5.9	−1.0	...	−5.1
90	+0.3	—	+1.0	−0.7	+5.4	—	−4.2	+1.4	−0.8	+4.5	...	+2.4
1	+1.3	−4.9	−2.1	−1.1	−3.7	−3.7	0.0	−0.9	+0.7	−2.3	...	−7.1
2	+1.2	+1.0	+0.9	−0.4	+3.6	+5.0	−4.4	−1.0	−2.3	+0.6	+5.1	−1.7
3	−3.7	−3.8	−6.3	−1.4	−6.3	−5.0	−2.2	−3.5	−9.6	−8.6	−3.0	−10.2
4	−0.2	−0.5	+0.2	−1.4	−5.2	−4.6	−1.3	+0.4	0.0	+3.4	−3.3	−1.1
5	−0.1	−1.6	−0.2	−0.8	−3.7	−1.0	−0.9	−1.7	−6.6	−1.7	−3.8	+0.5
6	+1.5	+1.4	+1.0	−1.9	+2.7	+4.0	+2.3	+0.5	+0.6	+0.6	+6.5	+0.9
7	+2.2	+1.2	+1.9	+3.2	−1.9	−0.3	−0.3	−1.8	−0.5	−3.4	−1.8	−1.1
8	+1.5	0.0	+0.3	0.0	+3.5	+5.5	+6.6	+2.1	+3.3	+7.8	−1.4	...
9	−1.8	−5.1	−0.6	+0.4	−1.4	−0.4	+2.4	+0.5	+3.2	+5.9	+2.3	...
1900	+0.4	−2.4	+5.6	+3.7	0.0	−2.0	+0.1	−3.0	−6.0	−8.1	−6.8	...
1	−1.4	−7.6	−2.2	+3.7	−3.6	−3.3	+1.2	...	+2.2	+1.1	−0.1	...
2	+1.1	+1.4	+3.5	+2.1	+6.0	+5.5	−0.3	...	+1.4	+8.3	+4.5	−4.3
3	−1.1	+1.3	+1.6	+0.5	+1.9	+0.9	+4.0	...	+1.6	+2.3	+0.5	+2.6
4	−0.5	−0.5	+1.0	−1.6	−2.8	−2.7	+0.6	−1.0	−4.2	+5.1	−5.2	−2.9
5	−2.2	−4.5	0.0	+0.4	−6.1	−5.5	+7.4	+2.8	+3.7	+4.5	−0.6	—
6	+0.6	−0.5	+0.1	+2.0	+0.5	0.0	−3.9	—	−2.2	−0.2	−1.2	—
7	+1.2	+2.0	+1.2	+0.5	+4.8	+5.8	+2.7	+2.7	+1.6	−0.4	+2.0	—
8	+0.7	−3.4	−0.7	+0.7	+2.0	−0.4	−5.0	−2.2	0.0	+2.8	+2.2	−1.7
9	−1.6	+1.5	+2.2	+1.6	−0.8	−2.4	...	...	...	...	...	...
1910	+0.5	−1.2	0.0	+1.7	−0.6	−1.8	...	...	...	...	...	...
* Normals, 1877-1906							−29.1	...	−21.3	−18.0	...	...

Station....	37 Ekaterinburg	38 Kizil Arvat	39 Kazan	40 Tiflis	41 Lugansk	42 Moscow	43 Elisabethgrad	44 Warsaw	45 Vienna	46 Abbassia	47 Laghouat
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude ..	56 50	39 17	55 47	41 43	48 35	55 45	48 31	52 15	48 15	30 5	33 48
Longitude.	60 38	56 10	49 8	44 48	39 20	37 34	32 17	21 1	16 22	31 17	2 53
Elevation .	289	100	80	409	45	156	123	120	202	30	780
Normal ...	−16°.5	−1°.4	−13°.8	+0°.5	−8°.3	−11°.1	−6°.5	−4°.6	−1°.3	+12°.3	+14°.7
Year											
1875	...	...	...	...	...	...	...	...	...	−2.2	...
6	−0.6	...	−0.1	−2.1	−3.7	+1.1	−2.0	−2.0	−3.1	−1.2	...
7	+0.9	...	−0.8	+1.9	+0.6	+1.5	−0.4	+3.2	3.0	−0.4	...
8	−0.2	...	−1.1	−0.9	−0.2	−0.8	−1.1	+1.4	0.1	−1.7	0.0
9	+1.8	...	−0.1	+2.0	+1.2	−3.1	+0.5	+0.3	−0.4	+0.8	—
80	−3.0	...	−2.0	−2.5	−3.0	−0.9	−3.5	+0.3	−0.6	−2.3	−2.4
1	+1.0	...	−1.7	+1.0	+1.0	−1.4	−2.5	−3.1	−3.1	+2.8	+5.7
2	+3.8	...	+5.6	+0.2	+6.5	+8.7	+5.4	+4.8	2.2	−1.0	−4.2
3	−2.5	...	−4.2	−3.4	−4.4	−4.8	−3.8	+0.6	−0.1	+0.5	−0.1
4	+2.6	+4.6	+1.7	−0.7	+2.7	+1.7	+1.7	+4.6	4.0	−1.9	—
5	−4.1	−1.4	−1.5	−2.5	−2.0	+1.1	−0.4	+0.8	−2.3	+0.3	−1.3
6	+5.0	+1.7	+1.8	+1.2	+5.5	+2.4	+4.3	+2.0	−0.1	+0.6	−0.1
7	−0.2	...	−0.2	−1.5	+3.2	+3.9	+3.5	+1.7	−2.2	+0.2	+0.3
8	−0.7	+6.8	−1.4	+0.2	+0.9	...	−1.2	−1.8	−1.0	−0.3	+0.9
9	−0.7	−5.8	−1.5	−4.6	−4.2	−3.0	−3.5	−1.7	−0.9	+1.7	−1.1
90	+1.5	+1.3	+2.7	−1.3	+2.4	+3.5	+1.9	+4.8	2.9	−0.3	+0.9
1	−1.9	−4.8	−7.3	−0.1	−3.6	−6.0	−1.2	−0.1	−4.6	+1.1	−2.0
2	−1.0	+2.9	−2.1	+1.3	+0.4	−1.3	−1.5	+0.1	0.5	+1.7	+0.8
3	−6.1	−3.9	−6.2	−2.6	−6.1	−9.4	−6.8	−8.4	−6.2	+0.5	0.0
4	+0.9	−3.5	+3.2	−2.4	−2.9	+2.3	−2.0	−0.6	−2.5	+0.3	+0.7
5	+1.3	−1.6	+1.2	+0.1	+6.8	+2.8	+6.9	+1.9	−1.0	+0.1	+0.6
6	−2.5	+6.0	−5.0	+1.7	−5.7	−2.1	−5.7	+0.4	−2.9	−0.3	+1.1
7	+1.6	−0.8	+0.9	+1.0	−0.7	+0.5	+0.5	−0.5	0.5	+1.0	+0.1
8	+4.0	−0.3	+3.3	−2.3	+2.8	+3.9	+2.6	+4.7	2.1	−2.4	−1.4
9	+5.1	+3.9	+6.1	+0.7	+7.7	+7.2	+7.3	+5.5	4.1	−0.7	+2.7
1900	−1.7	−6.5	−4.8	+1.0	−0.4	−2.3	+2.5	+1.9	2.1	+0.5	−0.2
1	−1.3	+2.2	+2.4	+0.5	+1.1	+5.0	+0.6	−0.4	−3.1	−0.2	−0.6
2	+0.1	+5.0	+1.4	+1.8	+7.8	+4.1	+6.8	+6.4	+4.7	−0.2	−0.2
3	+1.0	+2.1	+3.3	+0.2	+4.4	+3.8	+1.7	+2.9	−1.0	−0.7	−1.2
4	+3.5	−4.7	+1.8	−3.3	+0.5	+4.0	−0.6	+1.4	−0.7	−1.0	−3.0
5	+0.6	+1.4	−0.8	−0.5	+1.2	−0.3	−2.0	+0.2	−1.5	−2.0	—
6	−0.1	+0.5	+2.2	−0.2	+4.1	+4.8	+4.0	+3.1	+1.7	−0.9	+2.0
7	−4.3	+3.8	−2.6	+0.2	+0.4	−4.1	−0.1	+0.5	+0.6	−1.6	−1.9
8	−2.6	+1.7	−1.4	+0.2	—	+0.2	+2.2	+2.4	−0.9	−0.5	−0.6
9	+1.4	...	+0.2	−1.5	−1.7	+1.0	−3.0	+0.9	−0.8	−1.2	−1.9
1910	+3.1	...	+4.0	+2.4	+4.2	+4.0	+3.1	...	+2.3	−1.1	−0.6
* Normals, 1877-1906	−16.2	...	−13.9	0.0	−7.4	−10.3	−6.0	−3.4	...	...	...

All stations: Lat. N., Long. E. Stations 25-30 inclusive, F°; others, C°. Stations 25-30 inclusive and 47, departures from normals of maximum temperature; others, from normals of mean temperature.

* Employed for computing departures used in figures 111 and 113.

TEMPERATURE DEPARTURES FROM NORMALS—FEBRUARY

Station	Normal
Graaf Reinet	87°.8
Bloemfontein	84°.7
York	76°.7
Daly Waters	97°.4
Alice Springs	95°.5
Clare	84°.6
Deniliquin	94°.0
Bourke	93°.8
Carson	47°
Yuma	72°
Helena	30°
Salt Lake	41°
El Paso	62°
Cheyenne	37°
Bismarck	20°
Dodge	44°
Yankton	27°
Shreveport	59°
La Crosse	27°
St. Louis	43°
Atlanta	54°
Pittsburg	41°

TEMPERATURE DEPARTURES FROM NORMALS—FEBRUARY

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	+72°.8	+79°.6	+88°.8	+93°.7	+70°.6	+71°.4	−24°.0	−1°.5	−16°.3	−17°.0	+1°.0	−16°.4	−14°.3	+2°.9	−12°.6	+1°.9	−7°.4	−9°.8	−4°.2	−3°.3	+0°.9	+13°.7	+17°.8
Year																							
1875	+1.7	+4.5	−1.1	−1.0	+ 1.6	−1.9	+1.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	−0.1	...
6	+0.6	+5.8	+2.3	+1.0	+ 0.6	−0.8	+1.4	+0.6	−0.6	+2.0	−0.4	−0.1	+0.9	...	+1.2	+0.9	+0.4	+0.4	+1.2	+2.9	−0.6	+0.1	...
7	−0.1	−5.8	−4.7	+0.2	− 4.7	−5.0	+0.4	−1.8	−4.4	−2.6	+2.4	−2.5	−3.0	...	−4.1	+1.9	−1.2	−2.2	−1.4	+2.3	2.5	+0.5	...
8	−0.6	+3.0	+4.3	+4.7	− 3.1	−3.2	+2.5	−0.3	−2.6	+1.1	+2.7	+5.0	+3.4	...	+2.5	+0.8	+2.0	+2.6	+0.3	+2.9	2.7	−2.5	−2.2
9	+3.2	+4.0	+1.5	−1.0	+ 7.2	+6.0	−1.9	0.0	−4.0	+2.1	+2.7	+5.5	+1.5	...	+3.1	+2.0	+6.9	+4.6	+4.5	+2.5	1.4	+1.5	—
80	+1.2	−2.7	−0.7	+1.0	− 1.9	−2.2	−0.2	−1.3	−2.7	+1.6	−6.2	+0.5	−0.8	...	+1.6	−2.0	−5.3	+1.2	−5.7	+0.3	−1.6	+0.2	−0.2
1	+2.7	+0.2	+2.3	−1.8	+ 7.0	+7.5	+1.6	−2.5	−5.5	−3.4	+3.8	+2.6	−0.3	...	+0.7	+2.7	+2.3	+0.7	−1.1	+0.1	−0.8	+0.7	+0.4
2	+0.3	+1.5	+1.3	+2.4	− 1.7	+0.5	−1.6	−0.6	+1.7	+6.0	−2.3	+2.3	+1.9	...	+1.4	−3.0	+2.5	+4.8	+1.4	+3.6	1.8	−2.0	−5.2
3	−0.7	−2.8	+1.3	+0.2	− 0.6	+0.8	+0.7	−0.3	−2.0	−0.7	−8.6	−3.3	+2.0	...	+2.1	−1.7	−2.3	−0.3	−3.8	+1.4	1.4	−1.9	−0.6
4	−3.9	+1.9	−1.7	−1.1	0.0	−0.3	+5.5	−1.0	−1.8	+2.7	+0.6	+2.4	−1.2	+0.7	−0.5	−1.2	+4.1	+2.2	+3.0	+4.9	1.5	−1.2	—
5	−2.5	−2.0	−3.3	+1.7	− 2.6	−2.3	−0.1	...	...	−3.2	−1.3	+2.4	+3.5	−1.0	+3.2	+1.7	+4.0	+3.0	+1.6	+2.8	1.5	0.0	+4.7
6	−0.7	+0.3	−0.2	−0.9	− 2.7	−2.4	...	−3.0	−4.7	−7.3	−7.2	−1.4	−0.5	−8.1	−3.1	−1.3	−2.2	−3.5	−2.4	−2.5	−2.4	+0.9	0.0
7	−0.4	+1.1	+0.8	−0.2	+ 4.0	+3.0	+0.4	...	+0.5	+4.2	...	+4.1	+3.8	...	+3.5	−0.9	+1.3	+3.2	−2.9	0.0	−1.8	−0.6	−1.9
8	−1.4	+0.6	−0.6	+0.1	− 2.0	−0.3	−7.5	...	−4.6	−2.7	...	+0.8	−1.2	+3.6	+0.0	+1.7	+0.2	−0.6	−3.9	−2.3	−3.3	+2.1	−3.1
9	+2.2	—	+1.8	+0.3	−10.9	—	+5.4	...	−0.9	+3.4	...	+4.9	+2.3	+2.9	+0.9	+2.5	+6.6	−1.0	+1.1	−0.5	−0.9	+3.2	+1.2
90	+3.0	—	+3.5	+0.1	+ 5.4	—	−2.0	+0.7	−1.4	+1.8	...	+2.9	+2.0	−1.3	+3.5	−0.7	−0.3	+2.8	−3.1	0.0	−2.3	+1.4	−1.0
1	+1.7	−2.6	−3.8	−0.9	− 6.0	−7.6	+1.1	+1.2	−0.1	+0.1	...	+0.5	+1.8	+1.0	+3.5	−1.8	−1.1	+4.4	−4.7	−0.3	−2.4	−0.8	−2.1
2	+1.2	+2.3	+1.2	+0.6	+ 4.0	+5.3	−6.6	−2.0	−5.1	−2.4	+4.0	+6.4	+0.4	+1.8	+2.8	+0.5	+5.0	+2.6	+3.1	+1.6	0.9	+2.2	+0.9
3	−3.6	−9.2	−5.5	−0.8	− 9.7	−9.3	−6.2	−1.8	−3.3	−2.0	−1.9	−0.9	+1.9	−4.3	−0.5	−2.3	+2.0	−5.2	−2.1	+1.8	2.1	−1.1	+1.2
4	+3.2	−1.1	+2.3	−1.4	− 2.5	−1.0	+1.5	+0.8	+1.6	+5.9	+4.0	+7.4	+6.5	+1.6	+4.9	−0.2	+2.3	+4.3	+1.6	+2.7	2.6	−1.0	−1.1
5	+1.0	−0.8	−2.3	−0.8	+ 2.1	+5.4	−2.6	−3.5	−6.4	−3.4	+4.8	+1.9	−2.8	+4.3	−0.3	+2.9	+3.1	−3.0	−0.4	−3.4	−5.4	+2.6	+4.7
6	−1.7	+4.5	+4.3	+1.4	+ 0.7	+0.5	−1.4	−1.3	−2.1	+3.4	+3.2	+1.6	−0.2	+0.6	−2.7	−0.5	−0.6	−1.0	−0.9	+2.0	−0.3	+0.1	+0.2
7	0.9	+2.1	+4.8	+4.1	− 1.3	+0.9	+2.4	−2.4	−5.0	+0.7	+1.0	+3.4	−1.7	−0.2	−1.3	+0.2	+2.3	−0.2	+1.0	+0.9	2.1	−0.3	+1.6
8	−1.2	−2.4	−3.2	−1.6	− 1.4	+0.4	+4.1	+1.1	−5.2	−5.6	−1.5	...	−3.4	−0.2	−2.4	+1.3	+3.5	−0.2	+0.2	+2.8	2.1	+0.1	−0.7
9	−0.5	+1.9	+0.9	+0.5	+ 2.9	0.0	+1.3	+0.5	...	+1.3	+5.2	...	+2.0	+3.5	−0.2	+3.3	+1.5	+0.6	+1.2	+3.1	0.8	+0.2	+1.7
1900	−0.6	+0.1	+5.1	+3.9	+ 2.0	+0.9	+3.2	−0.1	+1.2	−1.0	−4.1	...	+1.8	−4.5	−3.0	+2.1	+1.6	−0.5	+2.1	+3.0	3.2	+1.6	+4.4
1	+1.3	−4.5	−4.6	−1.3	− 1.4	−0.7	+3.6	...	−2.0	+2.6	+1.3	...	+5.9	+2.4	+3.8	+4.0	+6.0	+1.8	0.0	−2.1	−4.3	+1.8	−2.9
2	+1.3	+2.7	+1.9	+0.2	+ 9.4	−2.0	+0.3	...	+3.1	+2.2	+2.0	...	+3.5	−0.4	+3.8	+2.0	+5.5	+2.2	+2.9	+1.3	−0.9	+2.2	+0.9
3	−0.3	+0.5	−0.9	+0.4	+ 3.0	+3.0	+5.1	...	+2.4	+9.0	+2.5	+9.7	+4.8	+3.3	+5.9	+0.3	+6.6	+6.0	+4.3	+5.4	+3.6	−1.6	−0.6
4	+1.1	+0.8	−0.3	−1.4	+ 4.8	+5.4	−1.3	−0.2	−3.5	+7.2	+3.8	+8.2	+2.7	+3.6	+5.2	+3.3	+7.7	+4.7	+3.2	+3.3	+1.6	0.0	−0.9
5	−5.4	−9.0	−4.6	+0.3	− 9.9	−8.9	+1.7	−2.1	−5.0	−0.1	−3.9	—	+4.0	−1.3	+3.4	−0.4	+4.3	+3.6	+1.0	+2.9	+0.5	−2.4	—
6	−2.2	−5.0	−1.4	+1.3	− 4.3	−6.3	−5.8	...	−4.4	−4.8	−0.6	—	−0.1	−1.0	−0.2	+1.5	+2.6	+2.4	+1.2	+2.6	−0.2	+0.1	−1.8
7	−0.1	−4.7	−3.0	+1.3	− 4.7	−4.2	−2.5	−3.0	−4.5	+0.1	−1.3	—	+2.6	−1.2	+0.9	−0.4	−0.4	−0.6	−2.9	−1.1	−2.0	−0.7	...
8	−0.8	−0.2	+1.6	+1.0	+ 4.5	+1.3	−0.5	−2.3	−3.7	−1.4	+0.5	−2.4	+1.7	+0.1	+0.1	+0.9	—	+1.6	+2.4	+3.2	+1.2	−1.2	−2.5
9	+1.1	+0.6	−0.3	+1.3	+ 0.6	−1.6	...	...	...	...	...	...	+3.0	...	+2.0	+0.8	−1.9	−0.2	−5.1	−2.8	−3.3	−0.9	−1.9
1910	+1.2	+2.8	+0.5	+1.4	+ 2.9	+2.2	...	...	...	...	...	...	+8.0	...	−1.8	+2.4	−3.2	+3.5	+3.8	...	+2.1	−0.7	−0.5
Normals, 1877-1906							−24.0	...	−18.7	−16.4	...	...	−13.0	...	−11.4	+2.5	−5.0	−8.5	−4.2	−1.9	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—MARCH

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	20°.3C	40° F	48°	61°	52°	39°	68°	41°	56°	32°	44°	70°	50°	40°	78°	52°	91°.5	87°.8	78°.8	91°.8	95°.8	71°.9	79°.9	82°.9
Year 1875........	−1.3	−6	−3	...	−3	−3	+2	−8	−3	−7	−8	...	−6	...	...	...	...	+0.7	...	...	...	...	...	...
6........	+0.5	−2	−2	...	−3	−4	−5	−12	−8	−8	−5	...	−3	...	...	...	+3.5	+5.2	...	...	...	...	...	...
7........	+2.4	−3	−3	...	−3	−6	+1	−5	+3	−3	+5	...	+8	...	...	...	−4.3	−0.2	...	...	...	...	...	...
8........	+0.4	+7	+8	...	+11	+17	+7	+15	+7	+18	+6	...	+7	...	+3	...	+4.3	−2.0	...	...	...	...	...	...
9........	−0.6	−1	+2	+6	+5	+5	+8	+9	+7	+2	+10	...	+10	...	+7	...	+0.3	−1.7	...	...	...	...	−4.5	...
80........	0.0	0	0	+3	−1	+3	−3	+4	0	0	−3	−1	−7	...	−5	...	−1.1	−4.0	−1.7	+7.1	...	−6.4	−5.2	...
1........	−0.1	+3	−5	−3	−4	−3	−4	−9	−3	+1	0	+1	+1	+7	+1	...	−2.0	−3.4	+0.1	−1.8	...	+2.0	−3.1	−5.9
2........	−0.4	+5	+4	+5	+5	+3	+7	+6	+7	+2	+4	+4	−5	−1	−1	...	+0.6	+1.1	+4.0	+2.9	...	−1.0	+0.3	+1.2
3........	+1.4	−3	−5	−2	−4	−5	0	0	−4	−1	+7	0	+6	+4	+3	...	−1.0	−3.9	−1.6	−0.9	...	−1.5	−1.3	+4.2
4........	+0.8	+2	+1	+1	0	−3	+2	−1	−1	−2	−2	+1	−1	−2	−6	...	+3.4	−0.2	+4.1	+2.9	...	—	−1.5	−3.0
5........	−1.0	−8	−8	−5	−2	−3	−2	+4	0	+3	+1	+2	+5	+11	+3	...	−0.2	−1.0	−4.8	−8.3	−3.8	−1.1	+0.2	−2.6
6........	+0.4	0	+2	−2	+2	0	−3	−4	−4	+4	−2	−2	−3	−1	−4	...	+6.0	+4.9	+0.9	+1.3	−0.1	—	−0.1	−2.0
7........	+0.9	−4	−2	+1	+3	−1	+6	+5	+6	+6	...	+5	+8	+10	+7	...	−3.3	+1.1	−0.8	0.0	+0.6	−1.0	+0.2	−4.9
8........	+0.1	−6	−2	0	−1	−9	−3	−6	−5	−10	−2	−2	−1	−7	−2	+1	+1.7	0.0	−3.7	−0.6	+2.3	+4.3	−1.7	−4.1
9........	0.0	+4	+3	0	+3	+10	0	+11	+3	+16	+8	−3	+8	+10	+2	+6	+5.6	+6.4	+1.1	+3.0	+7.1	+1.9	+4.2	+1.9
90........	−1.7	−1	−5	−2	−5	−5	−2	−4	+1	−3	+1	+3	−1	+2	0	−1	−2.9	+0.5	+0.6	+1.3	+1.3	−0.3	+0.2	+1.2
1........	+0.1	0	−2	−6	−6	−4	−4	−10	−12	−7	−5	−3	−4	−9	−2	−1	−1.3	+5.7	+2.1	+2.7	+5.5	−0.1	−1.8	+1.3
2........	−1.0	−3	−5	−4	−4	0	−6	+1	−9	+4	−2	−3	+2	+4	0	+5	+8.4	+8.4	+2.9	+2.8	+1.3	−1.3	+3.3	+1.9
3........	+0.4	−2	+1	−1	+1	−1	−2	−4	+2	−6	−2	−2	−4	−2	−3	−1	−1.8	+5.9	+3.8	+1.4	+2.9	+1.7	+4.2	+3.7
4........	−1.7	+8	+10	+6	+9	+9	+1	...	+4	+3	0	−3	−1	−1	0	+1	−4.2	−1.4	+2.0	+0.7	−1.4	−1.3	+1.3	+4.1
5........	+1.2	−3	−3	0	+1	+1	0	...	0	+9	−2	+1	0	+2	+1	+2	+3.7	−0.3	0.0	−1.0	−2.9	+1.3	+0.4	+4.2
6........	+0.5	−5	−6	−2	−3	−2	−1	...	−2	−2	−5	+3	−1	−3	+1	+1	−1.1	−1.5	+0.4	+3.9	−0.8	+1.7	+7.6	+5.3
7........	+2.4	+4	+6	+2	+3	−3	+4	−5	0	−11	−4	0	−9	−11	−8	−8	−5.4	−2.8	−5.2	−1.4	+1.3	−0.3	+1.9	+2.9
8........	−1.1	+11	+9	+5	+6	+6	+1	+5	0	+2	−2	−1	−5	−8	−4	−2	−1.3	+2.0	+0.7	−5.2	−3.9	+1.9	+1.9	+6.8
9........	+0.2	−2	+1	+2	−3	−10	+2	−12	−2	−14	−6	+3	−1	−8	0	−1	+0.2	−1.1	+2.0	−3.3	−7.3	−0.5	−2.0	...
1900........	+0.3	−4	−6	−2	0	−4	−2	+3	+1	+2	+3	+3	+9	+8	+5	+8	−0.5	−6.6	−4.0	−2.4	+4.5	−6.1	...	...
1........	+1.3	0	+3	0	0	−1	0	+6	0	+6	−2	−1	−1	+3	+1	+1	+2.2	−0.8	−1.6	−4.8	−6.2	−1.9	...	−4.1
2........	+1.5	+7	+5	−2	+2	+7	−1	+6	+2	+2	−3	−2	−4	0	−4	−6	+4.5	−1.8	−1.5	−0.1	+0.4	+3.1	...	+0.1
3........	+2.4	+12	+10	+2	+5	+6	−1	+3	−4	+4	−1	−2	+1	0	−1	−1	...	...	−0.6	−4.7	+0.4	−3.9	+2.6	−2.3
4........	−1.8	−1	+2	+2	+2	−1	+5	+5	+7	−4	+4	+6	0	−3	+2	−3	...	...	−3.4	−7.8	−3.9	+1.0	−2.9	...
5........	−0.2	+2	+8	+5	+8	+12	+4	+10	+4	+13	+4	−4	+3	+8	−2	+2	...	...	+0.1	−0.8	+5.0	−1.1	−2.5	...
6........	+1.4	−5	−7	−6	−13	−7	−6	−9	−14	−3	−10	+1	−2	−5	−1	—	...	...	...	...	...	+1.0	−1.3	...
7........	−0.8	+6	+7	+11	+10	+6	+9	+8	+11	+6	+8	+7	+2	+2	−3	—	...	...	...	...	...	...	...	...
8........	+0.6	+4	+6	+8	+7	+4	+6	+7	+8	+3	+6	+2	0	+3	+3	—	...	...	...	...	...	−4.1	...	−0.3
9........	+0.2	0	−4	0	0	−1	+1	−2	−2	+4	−4	−5	−1	+3	−4	—	...	...	...	...	...	...	...	...
1910........	−1.8	+10	+11	+10	+16	+18	+8	+23	+16	+25	+14	+5	+10	+16	+7	—	−5.8	...	−1.8	−10.1	−4.0	+1.3	...	...

TEMPERATURE DEPARTURES FROM NORMALS—MARCH

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent
Normal ...	+78°.7	+92°.4	+98°.1	+100°.3	+82°.9	+82°.5	−12°.9	+5°.1	−8°.6	−10°.9	+9°.1
Year											
1875........	−1.9	+3.6	+ 3.3	+0.3	+10.0	+11.3	+5.2	...	...	...	...
6........	−1.2	0.0	+ 0.5	+0.5	− 3.8	− 4.8	−0.2	+0.3	+0.7	+1.0	+0.5
7........	−0.1	−2.2	− 2.3	−0.6	− 3.7	− 0.6	+3.1	+0.3	+0.4	+4.1	+1.8
8........	+0.4	+2.0	+ 2.3	+2.7	+ 2.1	+ 0.4	+6.6	+3.0	+4.9	+4.2	+0.9
9........	+3.4	+2.0	+ 0.7	+0.3	− 1.7	− 4.4	−2.0	−1.8	−0.6	+2.0	+2.3
80........	+0.7	+3.5	+ 4.2	+0.8	+12.3	+11.1	+2.5	+0.8	+2.1	+5.4	−0.2
1........	−0.4	−3.9	− 3.1	−0.5	− 5.4	− 2.3	+1.4	+1.7	−1.6	+2.0	+1.4
2........	+1.0	+4.5	+ 4.0	+1.4	+ 3.3	+ 3.5	−0.6	+0.3	+4.9	+5.3	−5.3
3........	−1.4	−2.3	+ 0.2	−0.4	− 0.4	− 0.7	−2.2	−0.4	+1.3	+4.9	+0.4
4........	+1.3	+3.8	+ 0.7	0.0	− 0.3	+ 0.3	−1.5	−2.2	−4.1	−5.5	−3.9
5........	+1.7	+1.8	− 1.1	−0.1	+ 1.8	+ 2.2	+0.7	...	...	+1.6	+0.1
6........	+0.9	−0.7	− 1.3	−1.2	− 5.4	− 3.2	−0.1	+0.3	−2.1	−1.7	−1.4
7........	−1.0	+1.0	+ 1.9	−0.6	+ 3.6	+ 4.9	−0.8	...	+0.3	+4.8	...
8........	−0.5	+3.2	+ 0.9	+0.3	+ 5.6	+ 6.3	−2.1	...	0.0	+3.7	...
9........	+2.4	—	+ 1.5	−0.4	+ 1.6	—	−0.4	...	−1.9	+1.7	...
90........	−0.8	—	+ 0.3	−0.4	− 1.3	—	−2.1	−0.6	−3.2	−1.3	...
1........	−1.9	−7.3	− 5.2	−1.2	− 9.4	− 7.6	+3.7	+1.1	−0.9	+1.1	...
2........	+2.1	+4.0	+ 2.3	+1.1	+ 8.5	+10.0	−7.4	−4.1	−5.7	−4.5	−3.7
3........	−2.4	−6.7	−12.0	−5.3	− 4.7	− 3.3	+0.6	+0.2	+3.1	+7.0	−0.3
4........	−1.5	−2.2	− 0.3	−0.8	− 4.1	− 3.2	+1.0	+0.5	+0.9	+2.3	+0.5
5........	−1.6	−2.2	− 2.3	−0.7	+ 0.4	− 1.3	−3.7	−3.5	−1.3	+3.8	+3.2
6........	+0.1	+3.7	+ 3.0	+1.3	+ 0.3	− 0.7	−0.7	−3.1	−3.3	−2.5	+0.4
7........	+1.1	−1.1	+ 1.5	+2.3	− 2.3	− 2.3	−1.9	−2.7	−5.2	−2.5	−3.1
8........	+3.1	−0.5	− 0.7	+0.2	− 0.8	− 6.4	−6.0	−4.7	−9.1	−6.8	−6.2
9........	+0.3	+3.2	+ 2.9	+0.6	+ 3.5	+ 2.5	+1.7	+0.6	+0.5	+2.6	+1.7
1900........	−1.5	+2.8	+ 3.5	+2.0	+ 6.8	+ 4.0	+1.5	...	0.0	+3.6	+0.5
1........	+1.7	−2.9	− 2.8	−0.6	+ 1.5	+ 1.9	+1.6	...	+1.9	+4.7	+1.1
2........	+0.8	+4.1	− 3.4	+2.0	+ 3.7	+ 4.4	+1.3	...	+1.6	+3.2	−1.0
3........	+0.3	+0.2	+ 0.4	+1.3	− 3.8	− 5.8	+2.0	...	−0.9	−0.3	−7.4
4........	−1.2	−1.0	− 2.0	−0.8	− 6.2	− 6.7	−0.2	−1.7	−3.0	+0.6	−0.6
5........	−3.7	−7.8	− 2.6	−0.9	− 8.9	− 8.3	+2.4	−1.9	−4.0	−4.4	−6.3
6........	−3.1	−5.1	− 3.6	+0.1	− 7.2	− 6.6	−0.2	—	+2.7	+6.0	−1.4
7........	−3.5	−6.6	− 2.9	+0.2	− 7.3	− 5.7	−0.2	−0.8	−0.5	+2.2	−2.6
8........	+2.3	−2.6	− 2.8	−0.7	+ 1.8	− 0.5	−5.5	−1.9	−4.0	−0.9	−3.1
9........	+5.2	+2.0	+ 1.1	+1.2	+ 1.5	− 0.3	...	...	...	...	...
1910........	−1.6	+0.7	+ 0.3	+0.7	− 0.2	− 2.6	...	...	...	...	...
Normals, 1877-1906							−13.0	...	−9.4	−9.4	...

Station....	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	−8°.9	−8°.0	+8°.9	−7°.0	+6°.5	−1°.7	−4°.8	+0°.9	+0°.4	+5°.0	+16°.9	+20°.3
Year												
1875........	...	...	...	...	...	...	...	...	...	...	−1.4	...
6........	−0.1	+5.9	...	+3.4	+3.5	+4.0	+4.8	+3.9	+3.0	1.7	+1.4	...
7........	+8.0	+3.1	...	+3.0	+3.9	+4.9	+0.6	+0.4	−0.6	−0.2	+1.4	...
8........	+7.5	+5.4	...	+4.5	+0.8	+4.5	+2.4	−0.1	+0.8	0.6	−0.4	+0.4
9........	+7.3	+0.1	...	−1.2	+2.2	+1.4	−1.4	−1.0	−1.6	−0.5	+0.5	—
80........	+1.0	−2.2	...	−2.0	−3.9	−3.5	−1.7	−5.0	0.0	−0.3	−1.8	−1.2
1........	+4.4	+1.4	...	+0.2	+1.9	+3.3	−0.9	−2.1	−0.8	0.1	−0.1	—
2........	+1.2	+3.3	...	+3.2	−1.6	+4.7	+5.4	+3.4	+5.8	5.0	−1.0	−4.8
3........	+6.0	+1.5	...	+0.9	0.0	+0.7	−1.6	−3.9	−3.2	−3.8	−0.5	−2.5
4........	−7.3	−1.2	−1.7	−2.7	−0.7	−3.1	−2.2	−1.6	+1.9	1.4	−0.7	−0.7
5........	+1.2	+1.8	−0.2	+1.5	−0.7	+2.6	+1.8	−0.1	+1.8	1.0	+0.3	+0.6
6........	+0.6	−1.0	−0.2	−0.7	+0.3	+1.0	−1.1	−2.7	−4.1	−3.3	−0.8	+3.0
7........	+2.1	−0.2	...	−1.0	−0.5	+1.3	−0.5	−0.2	−0.8	−1.5	−0.8	+3.7
8........	−9.7	−0.4	+2.9	−1.1	+1.3	+1.8	−4.2	−1.0	−2.3	−0.3	+3.5	+0.6
9........	+2.3	−0.7	+1.7	−3.2	+1.1	−1.9	−3.5	−4.4	−3.2	−2.7	+1.8	−1.8
90........	+1.5	+3.0	0.0	+5.3	+2.1	+6.2	+4.0	+1.9	+3.4	2.1	+0.9	−3.1
1........	+5.3	+5.5	+0.2	+6.8	+1.3	+5.1	+4.2	+0.1	+1.7	0.4	+1.4	+0.6
2........	−3.3	+0.4	−2.2	−0.8	+0.1	+1.5	−0.1	−0.5	+0.4	−2.2	+0.4	+2.9
3........	+5.5	+5.4	+1.9	+4.3	0.0	+2.0	+0.4	−1.0	+1.8	1.8	−2.7	+1.7
4........	+1.6	−0.6	+0.7	−1.1	−1.0	+2.1	+1.0	+1.0	+3.9	2.2	−0.4	+0.3
5........	+8.7	+2.2	+1.8	+4.0	+0.7	+3.7	+1.7	−0.3	−0.4	−1.3	−0.8	+0.7
6........	−2.3	−2.4	−0.1	0.0	+0.6	−2.0	+0.7	−2.2	+3.7	2.2	−0.8	+1.8
7........	−1.3	−3.8	−2.4	−0.6	−0.9	+2.4	+0.3	+1.5	+3.2	3.2	−0.8	+2.8
8........	...	−7.2	−4.3	−5.2	−3.0	−4.1	−4.4	−4.3	+1.8	1.7	−0.3	−1.5
9........	...	−1.4	+2.6	−0.8	+0.8	+2.2	−1.5	−0.4	+1.5	0.1	0.0	−2.1
1900........	...	+2.9	...	+2.1	+0.5	+0.5	+1.6	−1.6	−1.3	−2.6	+1.0	−1.3
1........	...	+3.5	+2.6	+3.0	+3.5	+5.5	+1.3	+1.7	+0.9	−1.2	+2.1	0.0
2........	...	+0.2	+0.1	+0.4	+0.4	+2.4	+1.5	+0.4	+1.4	−0.4	+0.2	+0.7
3........	−1.8	+0.6	−5.0	+1.2	−2.4	+2.7	+3.4	+2.6	+5.3	+2.2	−1.6	+1.2
4........	...	+1.5	+0.6	−0.4	+0.5	+1.1	−0.1	−2.0	+0.4	−0.5	−1.7	−1.5
5........	...	−0.6	−4.7	−0.1	−1.2	+0.3	+0.6	−1.4	+2.0	+0.7	−1.6	—
6........	...	+4.4	+0.8	+5.1	+1.5	+6.4	+2.8	+3.0	+1.6	−0.1	−1.2	+2.5
7........	—	+1.2	−0.1	+1.0	−1.0	+1.2	+1.8	−2.1	−0.1	−1.7	−3.3	...
8........	−2.7	−3.3	−2.2	−3.9	−1.5	−1.0	(−1.4)	−0.9	+1.1	−1.4	−1.2	−1.6
9........	...	−0.3	...	−0.4	+1.6	−0.2	−1.0	−0.9	+0.5	−2.0	+0.4	+0.5
1910........	...	+1.2	...	+3.0	−0.1	+0.7	+3.5	+0.3	...	+0.3	−2.9	−0.9
Normals, 1877-1906	...	−6.9	...	−6.2	+6.8	0.2	−4.5	0.2	1.2	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—APRIL

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	16°.2 C	56° F	62°	70°	66°	58°	77°	60°	68°	54°	54°	79°	60°	54°	85°	60°	82°.3	77°.5	69°.0	82°.1	92°.4	64°.2	74°.8	76°.9
Year																								
1875	+0.2	−9	−4	...	−5	−5	0	−7	−9	−10	−6	...	−1	...	...	...	...	+5.4	...	...	...	...	...	...
6	+0.1	−5	−3	...	+1	−4	0	−2	+3	−4	+2	...	+1	...	...	...	−3.4	−1.6	...	...	...	...	...	...
7	+0.8	−2	+1	...	−2	−2	−4	−3	−6	−4	−4	...	−2	...	...	...	+1.3	0.0	...	...	...	...	...	...
8	−0.1	+3	+5	...	+3	+4	+2	+2	+1	+3	+3	...	−1	...	−1	...	+2.9	−0.7	...	...	...	...	−1.7	...
9	−0.4	−6	−3	−2	−1	+2	−2	+4	+3	+5	+3	...	+3	...	+2	...	−0.7	+0.6	...	...	...	...	−5.9	...
80	−0.3	+3	+3	+2	+2	−3	+1	+2	+2	−5	+1	...	−4	−4	−2	...	−1.7	−5.1	−0.5	+3.5	...	−1.2	−6.0	...
1	+0.1	−2	−6	−2	−6	−5	0	−12	+1	−6	+4	+6	+4	+3	+3	...	+0.2	−3.2	+2.5	+3.8	...	+2.2	−3.5	−6.1
2	−0.5	−1	0	+4	+2	−2	+3	−2	−2	−5	0	+2	−4	−5	−2	...	−2.8	−4.4	−0.9	+0.4	...	−0.6	+4.2	−1.0
3	−0.6	−2	−1	+1	+3	−1	+2	−1	−2	−2	−5	+1	−5	−4	−2	...	−2.8	−0.9	+2.7	+0.8	...	+0.9	+2.1	+0.9
4	−0.5	−2	−2	−3	−3	−3	−2	−7	−5	−6	−5	−1	−3	−3	−2	...	+0.8	+0.6	+0.3	+1.5	...	—	−1.6	+2.5
5	−1.0	+1	−1	+1	0	−5	+2	+1	0	0	−1	+3	+2	+2	0	...	+0.4	−0.7	−0.1	−1.4	−0.3	−1.0	−3.2	−2.9
6	0.0	+5	+5	0	+1	+3	0	0	−4	+4	...	+1	−2	+1	−3	...	+5.9	+7.7	+0.1	−1.8	+1.6	—	+1.5	−3.4
7	+0.1	−3	0	+3	+4	+1	+5	+4	0	+2	+1	0	0	−2	−1	...	+1.4	+2.4	−0.6	−4.4	−3.1	−3.3	−3.1	−3.4
8	+1.9	−3	0	+4	+5	−5	+2	+3	+4	+2	+7	+1	+7	+6	+5	+8	+9.4	+6.0	+6.3	+5.1	+3.6	+3.0	−2.4	−1.6
9	−1.6	+4	−1	+3	+1	+2	+2	+4	+1	+9	+3	+3	+6	+7	+5	+6	−0.4	+1.4	−1.8	+1.1	+5.7	+2.2	+5.5	+3.8
90	−2.4	+2	+2	+1	0	+2	+2	+4	−2	+6	0	−1	+1	+3	+2	+2	−3.3	+2.6	+1.8	−5.4	−3.4	+3.4	−4.6	−1.9
1	−0.1	+2	+1	+3	+1	0	−1	...	+1	+4	+2	−2	0	+4	+1	0	−1.8	−0.4	−1.9	−7.1	−3.2	+2.1	+13.2	+1.4
2	−0.1	−1	−3	−1	−5	−5	−3	−5	−4	−8	−4	−2	−4	−5	+1	+1	+1.4	−0.5	−3.6	−1.1	+2.4	−0.8	+2.8	+0.2
3	−0.3	−3	−2	+4	−1	−7	+1	−5	0	−8	−5	+1	−5	−6	0	−4	−2.9	−1.3	−3.6	+5.0	+5.2	−4.2	+1.2	+0.7
4	−0.5	+1	−1	+2	0	+1	+1	...	+4	−2	+3	0	−2	0	+3	+2	−3.4	−0.9	+4.0	−2.6	−3.2	0.0	−1.7	−1.8
5	+1.7	0	+1	−1	+3	+6	−1	...	+3	+11	+5	0	+3	+5	+2	+2	+4.7	+2.7	−1.9	+1.0	+0.2	−4.0	−3.5	+0.2
6	+1.3	+5	+5	+6	+9	+4	+2	...	+6	−2	0	+1	−4	−4	−4	−7	−0.8	−3.5	+0.3	+2.6	−1.7	−2.2	+4.8	+2.7
7	+2.0	+2	−2	−1	−2	−2	−1	−3	−2	−2	−3	+1	0	0	+4	+3	+4.7	+4.9	+5.0	+3.2	+6.4	+3.0	+7.5	+8.5
8	−1.0	−2	−5	−5	−3	−2	−3	+2	0	−3	+3	−1	+6	+2	+5	+6	+2.9	−2.3	−3.6	−4.3	−1.9	+0.8	+1.4	+3.7
9	+1.9	+2	+2	−2	0	+1	−3	0	+1	−3	+1	−2	+2	−5	+2	+1	+2.8	+2.2	+1.6	+3.1	−2.4	−1.0	−4.8	...
1900	+1.2	+2	0	+3	+1	+4	−1	+4	−3	+10	−4	−5	−2	+3	−6	−5	−1.0	−8.6	−5.1	0.0	+7.5	−1.6	...	+3.1
1	−0.5	+2	−4	−7	−3	+3	−4	+2	−3	+5	−2	−2	0	0	−1	−3	+2.0	−2.1	−0.7	−2.4	−2.6	+3.0	...	−0.5
2	+2.9	+1	−3	−2	−2	−1	+1	+1	+2	0	+1	+5	0	−3	+3	−3	+3.5	+4.0	+5.3	0.0	+2.2	+2.2	...	−0.7
3	−1.0	+2	−1	−3	+1	−1	−2	+2	0	+3	−2	−1	−1	−2	−2	−4	...	...	−2.2	−3.1	+0.9	−3.6	−2.1	−2.8
4	+1.7	−4	−7	−6	−8	−6	−4	−4	−2	−4	+1	+1	+1	+4	+2	−1	...	...	+5.8	−4.4	−4.8	+1.4	+0.8	...
5	−0.1	−20	−1	0	−1	−3	−3	−3	−4	0	−7	−6	+2	0	−4	+1	...	...	+1.8	−1.6	+4.0	+1.2	0.0	...
6	+2.3	+1	0	+4	+3	+3	0	+2	+2	+7	0	−1	−1	+5	−4	—	...	...	...	...	...	+2.4	+0.3	...
7	+0.1	−5	−9	−7	−11	−10	−7	−10	−6	−7	−3	0	0	−3	+1	—	...	...	...	...	...	...	...	...
8	−0.5	−1	0	+3	−1	+1	+2	+3	0	+6	+4	−4	+4	+5	+3	—	...	...	...	...	...	−0.6	...	−0.7
9	+0.8	−1	−3	+1	−2	−10	−3	−7	−2	−7	−6	−3	−4	−8	+2	—	...	...	...	...	...	...	...	...
1910	0.0	+5	+1	−1	−1	+6	−2	+5	+3	+12	+6	−2	+6	+12	+6	—	+2.4	...	+5.0	−0.8	−2.4	+3.0	...	...

TEMPERATURE DEPARTURES FROM NORMALS—APRIL

Station...	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	+81°.7	+102°.3	+105°.2	+103°.4	+95°.6	+93°.7	—0°.6	+13°.8	+2°.4	+0°.9	+14°.7	+6°.7	+1°.5	+15°.4	+3°.2	+11°.7	+7°.9	+3°.4	+7°.8	+7°.0	+9°.0	+21°.0	+24°.1
Year																							
1875........	—2.5	+3.2	+1.7	+0.9	+10.6	+11.5	—1.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—2.7	...
6........	+0.5	+0.6	+2.1	+2.2	— 1.7	— 1.1	+3.7	+3.2	+0.9	—1.1	—1.3	+1.4	—0.2	...	+2.2	+2.2	+5.0	+3.1	+5.0	+2.6	2.5	+1.6	...
7........	+0.2	—5.1	—5.8	—0.5	— 8.7	— 9.6	+1.5	+0.9	—0.8	—1.7	+2.1	+3.0	—2.0	...	—1.8	+2.5	+2.3	—1.8	+0.3	—1.8	—1.4	+6.3	...
8........	+3.2	—2.3	—5.2	+0.5	— 3.6	— 5.9	+2.4	+0.4	—0.1	+2.1	—0.2	+1.3	+0.2	...	+0.8	+0.5	+1.0	+1.5	...	+2.4	1.0	+2.0	+2.8
9........	+5.0	+5.4	+4.5	+1.5	+ 5.1	+ 3.2	—3.7	—2.8	—5.7	+0.9	+2.3	+3.9	+2.9	...	+1.7	+3.6	+4.0	+0.7	...	—0.6	—0.6	+1.3	—
80........	+0.8	+2.3	+3.0	+1.3	+ 7.6	+ 7.0	+1.1	—0.7	—0.5	—3.2	—1.7	...	—3.0	...	—3.9	—0.6	—1.4	—1.1	...	+2.7	2.1	+1.6	+1.1
1........	—2.3	+1.2	+0.8	+1.0	— 1.3	— 4.3	+3.9	—1.4	—1.1	+4.4	+2.3	3.4	+3.4	...	+2.1	+1.2	+1.2	—1.7	—1.1	—2.5	—2.7	+3.3	+0.3
2........	+0.9	+1.3	+0.8	+1.1	— 1.2	— 0.1	+1.8	+1.7	+0.9	—1.0	—0.8	—5.6	—2.0	...	—2.9	—0.9	—0.4	+0.3	+0.5	+1.9	0.2	—0.2	—1.0
3........	+1.8	+1.1	+2.3	+1.2	+ 2.2	+ 1.9	+1.4	—1.4	—3.4	—2.9	+0.9	—1.3	—3.7	...	+0.7	—0.4	—0.5	—0.3	—2.0	—1.6	—2.2	—1.6	—2.9
4........	+0.3	+1.6	—0.4	—0.1	— 1.1	— 1.0	—0.8	—0.7	—3.2	—3.5	+1.3	—2.6	—3.2	+1.7	—2.6	+0.7	—1.4	—3.0	—1.4	—2.0	—1.8	+1.7	+0.3
5........	—1.5	0.0	—2.7	+0.9	— 5.3	— 7.2	—1.8	...	...	—0.5	+0.3	—0.8	—0.4	—0.1	—2.1	—0.4	+1.3	—1.0	+1.4	+2.4	2.5	—0.7	—3.0
6........	+1.8	+0.9	+1.1	+0.7	— 1.1	+ 1.2	+3.8	+0.2	—1.1	—2.4	—1.8	—2.8	+0.4	—0.8	+0.5	—1.7	—0.1	+2.3	+0.9	+2.4	1.3	—0.5	—1.4
7........	+2.7	—0.1	—0.4	—1.4	+ 3.1	+ 3.7	—0.6	...	+0.7	+2.7	...	+0.5	+0.6	...	+0.5	—0.3	—0.6	+1.3	—1.0	+0.7	0.2	+0.9	—1.1
8........	—1.1	+2.3	+2.7	—0.2	+ 2.4	+ 2.5	—2.1	...	—4.0	+1.6	...	+6.2	+5.0	+2.7	+6.3	+1.6	+5.4	+2.3	+2.4	—0.7	—1.2	+0.4	+1.5
9........	+0.9	—	+1.2	+0.6	+ 1.9	—	—0.9	...	—2.2	+1.6	...	+1.9	+2.4	+0.6	+2.5	+0.8	+1.7	+0.6	+0.8	+0.9	0.0	+0.5	0.0
90........	+2.0	—	—0.5	—1.4	+ 0.3	—	—1.3	—1.2	—2.7	—0.7	...	+1.3	0.0	+1.0	+2.2	+1.2	+3.2	+4.7	+2.9	+3.5	—0.1	+1.2	—1.7
1........	—0.3	—1.0	—0.8	—0.1	— 3.9	— 1.2	—0.9	—1.5	—2.7	—3.3	...	—1.2	—1.0	+1.9	+1.2	+0.1	+0.2	+1.9	—0.9	—0.9	—2.1	+1.2	+1.5
2........	+2.7	+3.5	—0.4	+6.5	+10.3	+11.4	—1.0	+0.5	—2.1	—1.2	+0.8	—2.7	—1.6	—0.7	—1.3	—1.3	—0.4	—0.2	+1.1	0.0	0.5	+0.6	—1.9
3........	—1.0	—0.8	—1.4	—1.2	— 0.6	+ 1.0	+3.4	+0.7	+2.2	+7.8	+1.0	+3.5	+1.6	+0.4	—1.5	—2.2	—2.8	—3.1	—3.8	—1.3	0.3	—1.9	+0.7
4........	+0.9	—0.3	—1.0	—2.0	— 0.1	+ 0.7	+1.9	+0.6	—3.2	—3.8	—1.6	—2.7	—2.2	—0.8	—1.2	—1.3	+0.8	+2.0	+0.9	+3.0	3.1	—1.6	—0.1
5........	+0.2	—4.6	—3.0	—3.4	— 1.4	+ 1.1	+1.7	+0.7	—0.4	+0.9	+2.1	0.0	—2.6	+1.4	—2.8	—0.5	—0.7	—1.3	—0.6	+1.5	—0.3	—0.1	+5.2
6........	—1.1	+3.8	+3.7	+2.4	+ 0.8	+ 0.8	+0.1	—1.4	—1.0	—1.1	—1.9	—3.0	—2.8	—1.4	—3.5	—2.3	—4.0	—2.1	—3.1	—0.8	—1.9	—1.5	—0.8
7........	+2.3	+1.6	+1.0	+0.8	— 3.3	— 3.9	+2.3	—1.7	—1.4	+2.3	—1.5	+0.5	+0.3	—0.1	0.0	+0.7	+3.3	+2.2	+2.7	+1.4	0.0	—1.2	+0.9
8........	+0.4	+3.1	+1.4	+0.4	+ 5.2	— 0.7	+1.1	—0.3	—0.5	—1.6	—1.9	...	—0.8	—1.5	—2.6	—1.3	—2.2	—1.6	—1.0	+0.1	—1.5	—0.2	—1.6
9........	—0.9	—1.8	—3.4	—4.5	— 1.2	+ 1.8	+1.6	+0.1	+1.5	+1.8	+0.7	...	+1.7	—3.9	+1.6	+2.2	+3.1	+1.2	+2.0	+1.1	0.3	—0.8	+1.9
1900........	—1.8	—0.4	+1.8	+0.2	— 3.7	— 6.0	+1.5	...	—4.1	—1.0	—1.6	...	—2.0	+0.6	—1.6	+0.1	—0.1	—0.5	—0.4	—0.3	—1.3	—0.5	—2.2
1........	—1.3	0.0	—2.0	+1.3	— 2.8	— 1.1	+1.2	...	—1.4	+3.3	+0.2	...	+3.8	+2.6	+4.8	+2.0	+3.2	+1.5	+0.7	+0.7	+1.3	+0.1	+2.1
2........	—3.7	+1.1	+1.1	+1.5	+ 0.5	+ 2.1	—1.8	...	—3.2	—0.9	—1.7	...	—1.9	—0.1	—2.5	+0.2	—0.5	—2.0	—1.6	—1.9	+0.0	0.0	+1.5
3........	+0.1	—0.3	+1.0	+1.3	— 4.4	— 5.2	+1.5	...	—1.8	—1.5	—1.5	—0.8	+3.6	+0.9	+4.7	+2.1	+5.4	+5.5	+2.1	+0.1	—2.5	—0.2	+0.2
4........	—3.1	+1.7	+3.0	+0.4	+ 0.7	+ 0.9	+1.7	—2.0	—3.9	—1.8	—1.7	...	+1.4	—1.0	—2.1	—2.0	—0.8	+0.8	—0.5	+0.2	+1.2	—2.5	—0.1
5........	—3.7	—6.6	—4.2	—0.3	— 3.1	— 2.5	—0.2	—3.5	—3.9	—2.5	—0.6	...	0.0	+0.5	+1.4	+0.3	+0.5	+0.8	0.0	—1.2	—1.4	—0.7	—
6........	—4.1	—0.2	+2.5	+4.0	— 2.8	— 2.6	+3.3	...	+2.1	+3.9	—2.8	...	+3.4	—0.6	+4.2	+0.9	+3.1	+4.5	+1.9	+3.0	+1.4	—0.7	+0.4
7........	—1.6	—7.1	—7.9	—4.5	— 6.4	— 4.3	+3.6	+0.2	—0.5	+1.0	+1.2	...	2.0	+1.3	+1.6	—0.7	—0.5	+0.4	—1.6	—1.2	—2.0	—1.1	—2.3
8........	+2.6	+3.1	+1.7	+1.7	+ 0.6	— 1.7	0.0	—1.3	—2.4	+0.1	—0.3	—4.9	+2.0	+0.4	—0.8	—0.8	—0.5	0.0	—0.8	—0.9	—1.1	—1.8	—1.6
9........	—1.2	—4.9	—7.3	—1.5	— 3.9	— 2.2	...	...	...	...	...	...	+2.7	...	—0.3	—0.5	—0.7	—1.1	—1.1	—0.7	+1.1	—2.8	+2.0
1910........	—1.3	+0.6	+1.3	2.7	— 3.5	— 5.4	...	...	...	...	...	...	+2.5	...	+2.9	—1.2	+2.9	+4.5	+2.0	...	—0.3	—0.4	+1.8
Normals, 1877-1906							0.1	...	0.7	0.9	...	...	1.5	...	3.3	11.9	8.7	3.9	8.1	7.4	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—MAY

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton
Normal ...	12°.8C	69° F	73°	79°	71°	69°	83°	70°
Year								
1875........	+1.3	—2	+2	...	— 3	0	+7	+ 3
6........	+1.4	—4	+1	...	+ 5	0	—1	+ 2
7........	—1.6	—3	—2	...	+ 1	+ 3	—1	— 3
8........	—0.7	—4	—3	...	0	— 5	0	— 6
9........	—0.4	+2	+3	0	+ 3	+ 2	+1	+ 5
80........	+0.4	+6	+9	0	+ 9	+ 6	+2	+ 8
1........	+0.2	+4	+6	+1	+10	+ 8	+3	+ 7
2........	+0.8	—6	—5	—4	— 2	— 6	0	— 5
3........	+0.4	—2	0	—2	+ 2	— 8	+3	— 8
4........	—1.8	—2	+2	0	+ 3	— 1	—1	+ 1
5........	—1.5	—1	0	—4	+ 2	— 2	0	0
6........	+0.5	—1	+2	—1	+ 7	+ 3	+7	+ 6
7........	0.0	+7	+6	+3	+ 8	+ 8	+5	+ 7
8........	—0.5	—2	—2	—1	+ 2	—10	—1	— 9
9........	—0.3	+4	—1	0	+ 2	— 2	—2	+ 2
90........	—0.7	—2	—2	0	+ 3	— 6	0	— 2
1........	—0.3	—1	—4	—1	+ 2	+ 1	—3	...
2........	—1.1	—5	—3	—1	— 1	— 9	—2	—11
3........	—0.6	—1	—3	—3	+ 1	— 2	—1	— 2
4........	+1.4	0	—1	0	+ 4	+ 1	0	...
5........	+0.8	+3	+1	—3	+ 5	+ 2	—3	...
6........	+1.9	+5	+6	+6	+11	+ 6	+4	...
7........	+1.0	—1	—5	—1	+ 1	— 1	0	+ 2
8........	+1.1	—3	—1	+5	+ 5	+ 1	+2	— 2
9........	+3.8	+1	+1	+5	+ 6	0	+4	0
1900........	+0.9	+1	+3	+1	+ 7	+ 5	0	+ 6
1........	+2.6	—2	—2	0	+ 4	+ 3	—1	+ 3
2........	+2.6	—2	+2	+5	+10	+ 2	+2	+ 5
3........	+0.5	+5	+3	—3	+ 6	+ 2	—5	+ 1
4........	+0.6	+4	+1	—1	+ 3	+ 1	—1	+ 2
5........	—0.6	0	0	+1	+ 5	— 4	+1	— 4
6........	+2.4	0	—1	—2	+ 6	— 1	+1	+ 1
7........	—1.8	—7	—7	—3	— 3	— 9	—6	— 7
8........	—0.2	+1	—1	0	+ 4	0	—1	— 1
9........	—1.4	—2	—3	—3	+ 1	— 1	—3	0
1910........	—0.8	—1	—7	—3	+ 2	— 3	—3	— 4

Station....	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson
Normal ...	76°	67°	64°	87°	69°	63°	93°	67°
Year								
1875........	+1	+ 1	+4	...	+2	...	...	...
6........	+1	+ 1	0	...	—1	...	...	...
7........	—1	— 1	—1	...	—1	...	...	...
8........	—2	— 7	—3	...	—1	...	+1	...
9........	+5	— 3	+7	...	+1	...	+1	...
80........	+7	+ 4	+5	+3	—4	—4	+1	...
1........	—2	+ 6	+4	+3	+2	+2	+2	...
2........	—8	— 4	—5	+3	—1	—3	0	...
3........	—2	— 6	—3	+2	—1	—3	—1	...
4........	—5	0	+1	+4	—1	+2	—2	...
5........	—5	0	—3	+3	—2	0	+2	...
6........	+7	+ 6	...	+9	+6	+5	+4	...
7........	+3	+ 8	+5	—1	+4	+2	—1	...
8........	—2	— 6	—4	—2	+1	—2	—1	+2
9........	0	— 3	—3	+2	+1	+1	+1	+3
90........	+1	— 3	+1	+3	+4	+1	+1	+5
1........	—3	0	0	—4	+2	+4	—4	—1
2........	—8	—12	—8	—3	—4	—6	0	+3
3........	—2	— 3	—4	—3	—3	—1	—1	—2
4........	+2	0	+2	+1	+3	+3	0	+2
5........	+2	0	—2	—2	0	0	+2	+1
6........	+5	+ 2	0	+3	—7	—8	—1	—5
7........	0	+ 4	+4	+1	+7	+9	+3	+7
8........	—3	— 3	—7	—2	—5	—5	—3	—3
9........	+5	— 5	—1	—1	—5	—7	—5	—7
1900........	0	+ 2	+4	0	+3	+3	+1	+2
1........	0	+ 8	+2	—1	+5	+4	—3	0
2........	+2	+ 2	+1	+1	+1	—1	—2	—3
3........	—4	0	—4	—4	—4	—3	—1	+1
4........	—1	— 2	—3	—2	—1	—1	0	+3
5........	—2	— 5	—6	—2	—4	—4	—7	—6
6........	+1	— 6	0	—1	—2	—5	—4	—
7........	—6	— 9	—8	—6	—3	—4	—4	—
8........	+2	— 3	—4	—5	—7	—5	—3	—
9........	0	— 1	—5	—5	—5	—3	—1	—
1910........	—5	— 1	—3	—1	+2	+5	+5	—

Station....	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	72°.4	67°.6	61°.8	73°.7	88°.2	57°.1	67°.1	71°.6
Year								
1875........	...	—2.8	...	...	...	...	...	...
6........	—3.0	—1.3	...	...	...	...	...	...
7........	—0.6	—1.7	...	...	...	...	...	...
8........	+1.5	—2.3	...	...	...	...	—1.2	...
9........	—4.8	—6.0	...	...	...	...	—2.7	...
80........	+1.6	—4.0	0.0	+6.1	...	+0.9	—2.8	...
1........	—0.4	—1.5	+3.6	+6.7	...	—0.1	+0.1	—1.8
2........	0.0	—2.6	+1.4	—2.0	...	—1.3	—1.1	—3.6
3........	+1.0	—1.8	—2.6	+1.4	...	+1.3	+2.8	+1.4
4........	—1.2	—0.7	—0.7	—1.8	...	—	+0.3	—1.2
5........	+3.6	+1.5	+2.8	+9.3	+3.4	—0.7	—4.1	—2.0
6........	+5.4	+4.2	—0.8	+2.1	+1.6	—	+2.5	+2.3
7........	—0.1	+2.8	—3.5	—	—3.8	—1.9	—2.5	—1.6
8........	+1.1	+2.7	+0.5	—0.9	+2.4	—0.3	—1.6	—5.2
9........	+2.1	+2.3	—1.6	—3.6	+2.6	—1.3	+6.8	+3.4
90........	+1.8	+4.9	+1.5	—1.3	—1.7	+1.0	—3.8	—1.7
1........	—3.4	+3.1	+4.4	+3.0	+1.8	+1.3	—0.7	—1.1
2........	+0.4	+0.2	—0.8	—0.7	+1.0	—0.2	+7.6	—0.3
3........	+2.2	+2.5	—0.7	+2.8	+4.2	—1.5	+2.9	—1.5
4........	—2.8	—0.8	+0.6	—4.4	—5.3	+0.7	—0.7	—0.6
5........	+2.2	—0.1	—1.5	—4.1	+0.5	—0.1	+2.0	+2.0
6........	—0.5	—2.3	—0.4	—0.3	—3.1	+0.9	+0.9	+3.1
7........	+2.6	+3.2	+3.1	—0.2	+2.8	+1.5	+5.9	+3.8
8........	—2.3	—1.2	—4.6	—5.3	—3.1	+1.3	—1.0	—0.5
9........	+3.2	—0.1	—0.8	—1.1	—3.5	—0.9	—7.2	...
1900........	—1.5	—2.4	—3.3	—5.0	+3.4	—1.9	...	+4.1
1........	+4.5	+3.5	+4.6	+0.3	—1.7	+0.7	...	—0.8
2........	+5.5	+3.8	+4.1	+1.2	+1.5	+1.2	...	+4.0
3........	...	...	—2.1	—6.3	—1.6	+0.3	—0.8	—0.1
4........	...	...	+2.6	—3.7	—4.2	—1.3	—0.1	...
5........	...	...	+1.8	+1.8	+4.0	+1.5	+0.4	...
6........	...	...	...	...	...	+2.1	+1.4	...
7........	...	...	...	...	...	...	...	...
8........	...	...	...	...	...	—0.4	...	—0.3
9........	...	...	...	...	...	...	...	...
1910........	+2.8	...	+2.7	+3.2	+1.6	+0.8	...	...

TEMPERATURE DEPARTURES FROM NORMALS—MAY

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz
Normal ...	85°.6	105°.1	109°.1	102°.4	103°.8	103°.7	8°.0	19°.9	9°.1	10°.6	21°.2	17°.1
Year												
1875........	+2.1	+0.6	+1.1	+0.1	+ 4.2	+ 5.9	+1.9	...	...	...	...	...
6........	−0.8	+2.5	+2.0	+1.2	+ 0.1	− 0.8	−1.9	+2.7	+0.6	+0.7	−0.4	−0.5
7........	−1.4	−1.6	−4.2	+0.2	− 6.1	− 7.3	+1.0	−1.6	+0.7	+1.2	+3.5	+1.1
8........	+0.7	−4.9	−2.7	+1.7	− 7.8	− 7.4	+1.0	−0.5	+2.6	+3.7	+0.3	+1.0
9........	+1.0	+5.2	−2.2	−2.7	+ 4.4	+ 0.9	−1.6	−0.1	+3.1	−1.5	+3.7	+4.8
80........	+3.2	−2.5	+0.8	+2.0	+ 3.1	+ 2.7	+0.6	+1.1	+0.0	+1.3	+0.5	+0.1
1........	+1.8	−1.3	+1.8	+2.0	+ 0.9	+ 0.7	0.0	+0.7	−1.1	+0.5	−0.1	+0.2
2........	+1.3	−2.0	−0.9	+0.9	+ 0.8	+ 1.4	+2.4	+1.2	0.0	+1.6	−0.8	+0.1
3........	−0.2	+1.6	+2.5	+2.9	− 0.5	− 1.6	+1.2	−1.1	−1.7	−2.0	+0.8	+2.0
4........	−0.3	+0.9	+0.4	+0.9	+ 1.1	+ 0.6	+0.4	0.0	+1.4	+3.1	−1.0	−2.2
5........	−2.0	−2.2	−4.6	−0.7	−13.5	−10.5	+0.4	...	...	−0.8	±0.0	−0.4
6........	+2.2	−1.5	−1.3	−1.1	− 1.9	− 0.1	+3.2	...	−0.4	−1.3	−2.9	−1.1
7........	+3.5	−1.0	+1.1	−2.0	+ 5.5	+ 6.8	+1.3	...	−0.2	−0.3	...	+0.4
8........	−1.5	+2.2	−1.0	−3.7	+ 1.7	+ 2.7	−0.8	...	−1.3	+3.1	...	+3.5
9........	−3.0	—	+1.2	+2.0	− 2.8	—	−0.3	−0.8	−0.5	−1.6	...	−0.9
90........	+2.5	—	+2.5	−0.7	+ 0.5	—	+1.2	+1.5	+0.2	−3.0	...	−1.9
1........	−2.4	−1.3	−0.9	+0.6	− 4.2	− 3.3	+1.1	+2.5	−0.2	−0.6	...	+0.3
2........	−2.2	+2.5	+1.0	+1.0	+ 2.6	+ 5.3	+0.5	+0.6	0.0	+3.0	±0.0	−0.1
3........	+3.0	−4.5	−2.9	−3.8	− 3.1	− 0.9	+0.8	−1.7	+1.2	−1.0	−0.3	−1.2
4........	−1.4	+3.3	+1.3	−2.0	+ 2.5	+ 3.1	+2.2	+0.5	0.0	+1.4	−0.8	+1.0
5........	+2.7	+0.1	+1.4	−0.7	+ 5.7	+ 5.4	+0.3	−1.2	−0.7	+0.8	−1.1	−1.6
6........	0.0	+3.0	+3.1	+0.5	+ 3.9	+ 2.1	−0.4	−0.3	−1.0	+3.3	+0.1	+1.1
7........	−2.3	+4.1	+2.9	+2.8	+ 0.9	+ 1.0	+0.3	−0.5	−2.0	−1.6	−1.2	+3.0
8........	−0.2	+1.6	+0.4	+0.3	− 1.9	− 3.0	−0.9	+1.9	−2.4	−4.1	−1.2	...
9........	+0.6	−0.9	−0.8	−1.4	+ 1.9	+ 4.2	+0.4	+1.0	+0.1	+2.9	+0.4	...
1900........	+0.1	−1.6	+1.2	+1.3	+ 0.6	− 2.7	+2.2	−9.7	+0.4	+4.0	+1.7	...
1........	+1.0	+0.8	−0.4	−1.8	− 1.3	− 3.8	+2.0	−3.3	+0.3	+1.1	−1.5	...
2........	−0.6	+0.5	+1.6	+1.8	+ 1.9	+ 3.1	−2.3	...	−3.2	+0.8	+0.3	...
3........	−1.9	+1.8	−4.4	−1.0	− 2.2	− 4.8	+0.7	+0.7	−1.2	−0.3	−2.3	−0.2
4........	−2.4	−1.3	0.0	−1.0	+ 1.4	0.0	+1.9	−1.2	+0.1	+4.1	+0.2	...
5........	−0.9	−2.3	+1.7	+0.9	+ 3.6	+ 2.7	−0.1	−0.6	−0.3	0.0	−1.4	...
6........	−1.2	+1.5	+2.4	+3.3	+ 4.7	+ 1.7	+3.0	...	−1.9	−1.2	−0.8	...
7........	−1.1	−2.0	−1.4	+1.7	− 1.7	− 1.7	+2.8	+1.2	+0.7	+1.1	−3.0	...
8........	−0.6	+2.0	+0.7	+0.8	+ 1.1	− 0.9	+0.4	+0.9	+1.8	+5.1	−1.5	−1.7
9........	−2.6	+2.0	−1.7	−1.9	+ 0.6	− 1.0	...	...	...	...	...	...
1910........	+0.5	+1.5	−0.3	+0.5	+ 2.2	+ 0.1	...	...	...	...	...	...
Normals, 1877-1906							8.7	...	8.5	11.5	...	...

Station....	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbasia	Laghouat
Normal ...	9°.4	23°.5	11°.9	17°.5	15°.0	11°.6	15°.7	13°.1	13°.6	24°.9	28°.0
Year											
1875........	...	...	...	...	...	...	...	...	...	−1.8	...
6........	−1.5	...	−2.5	+1.9	−0.6	−4.0	−2.8	−3.7	−3.4	+1.4	...
7........	−1.0	...	+0.8	0.0	+0.4	+0.4	−0.6	−1.6	−2.1	+5.8	...
8........	+0.1	...	−0.3	−1.0	+1.1	−1.5	−0.3	−0.3	0.5	+0.8	...
9........	+1.9	...	+2.7	+2.5	+3.0	+1.1	+0.4	−0.3	−1.7	−0.4	...
80........	+2.8	...	+2.5	0.0	+0.9	+1.3	−1.2	−1.2	−1.3	+0.9	0.0
1........	+2.7	...	+1.9	+0.6	+1.3	+1.0	−0.6	+0.5	−0.6	−0.2	−2.3
2........	+1.1	...	+1.7	−0.5	+2.4	+2.8	+1.0	+0.5	0.8	−2.2	+0.5
3........	+3.1	...	+4.4	+1.3	+3.2	+3.5	+1.0	−0.5	0.8	−1.6	−0.4
4........	−0.5	−1.2	−2.2	−1.8	−0.2	−1.8	−1.1	−0.2	1.1	−1.3	−0.7
5........	+1.0	+1.7	+0.8	+3.2	+1.9	+1.0	−0.7	−1.2	−1.6	+0.1	−0.4
6........	−2.2	+1.0	+0.3	+0.1	+2.7	+0.6	+0.5	+0.9	0.3	−1.7	−0.1
7........	+3.2	...	+3.7	+1.0	+3.4	+4.1	+2.1	−0.5	−1.3	−0.7	+2.6
8........	+2.9	+1.6	+1.8	−0.3	+0.9	−0.2	−0.8	+0.5	1.2	−0.6	−0.3
9........	+1.8	−0.7	+3.3	0.0	+2.7	+4.4	+1.8	+4.8	3.7	+1.3	+0.9
90........	−4.5	+0.3	−1.0	+1.0	+2.7	+2.7	+0.9	+3.0	1.7	+0.8	+0.6
1........	+1.6	−1.2	+3.1	−0.7	+2.3	+3.7	+1.3	+2.3	2.0	+1.3	0.0
2........	+2.8	−0.9	+3.1	−1.3	+1.6	+2.4	+1.5	+1.2	0.0	−1.2	3.0
3........	−1.5	+0.1	−0.5	−0.7	−0.4	0.0	−1.9	−0.3	−0.1	−2.6	+3.6
4........	+2.5	+1.3	+4.3	+0.9	+2.1	+2.3	−0.7	+1.4	0.6	−0.8	+1.4
5........	−1.6	−0.8	−0.9	−1.8	−1.0	+1.0	−1.4	+2.4	−0.5	−0.1	+0.1
6........	+2.9	−1.3	+1.3	−2.4	+0.4	−0.4	−1.3	±0.0	−1.5	−0.6	−2.5
7........	+4.5	+0.2	+5.8	+1.0	+3.6	+6.3	+1.7	+2.3	−1.4	−0.7	+1.7
8........	+2.1	+0.6	+4.7	−0.5	+3.2	+4.7	+1.7	+2.2	0.3	−1.1	+0.7
9........	+0.7	+0.5	+0.9	+0.6	+1.5	+0.5	+1.1	−0.1	−0.6	−0.6	+1.6
1900........	+2.7	+0.3	+1.0	−0.7	+1.4	−1.2	+0.7	−0.6	−1.3	−2.2	−2.1
1........	+1.2	+0.4	+1.0	−0.9	+1.3	+0.3	+0.2	+2.0	+1.2	−0.8	−2.4
2........	+0.4	+0.4	+1.0	−0.5	+1.5	+0.6	−1.8	−2.3	−3.0	−0.4	−1.8
3........	−1.5	+0.7	+0.8	+0.7	+2.0	+1.6	+0.2	+1.3	+0.7	−0.6	−0.5
4........	+2.0	+0.5	−0.1	−2.0	−1.1	−1.6	−1.8	−1.6	+0.2	−2.7	+4.4
5........	+1.3	−1.4	+3.9	−1.9	+3.1	+4.0	+1.4	+1.9	+0.4	−0.7	—
6........	+3.6	+1.2	+6.8	+0.2	+6.1	+6.5	+2.6	+3.6	+1.2	−1.6	+1.6
7........	−2.3	−0.7	−2.2	+0.9	+2.7	−0.7	+2.5	+2.2	+2.2	−1.8	+2.1
8........	−1.1	−1.2	−2.5	−0.8	−0.6	−1.8	+0.1	+0.9	+3.0	−0.8	+4.6
9........	−0.3	...	−0.5	+1.9	+1.6	−2.3	−0.7	−2.0	−1.1	+0.7	−0.3
1910........	+049	...	+1.2	0.0	+1.7	+2.2	+0.9	...	−0.1	+1.1	+2.4
Normals, 1877-1906	10.6	...	13.8	17.4	16.8	13.3	15.9	13.8	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—JUNE

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne	El Paso
Normal ...	9°.7C	78° F	82°	85°	84°	78°	90°	73°	85°	75°	75°	94°
Year 1875	-3.1	-1	0	...	-3	-4	-1	+3	+4	-3	+4	...
6	+0.1	+2	+3	...	-3	-2	-2	+5	-1	-3	+1	...
7	+0.3	-2	+1	...	-1	-3	0	+2	-3	-7	-2	...
8	-0.3	-4	-4	...	-4	-2	-2	+3	-3	+1	-3	...
9	-0.1	-3	-1	-2	-1	0	-1	+8	+5	0	+5	...
80	+2.2	+2	+2	0	-1	+1	-2	+7	+4	-1	+3	...
1	-0.9	-5	-3	+1	+2	-2	+7	+10	+7	+1	+8	+7
2	+0.1	-1	-1	0	0	-3	+3	+6	+1	0	-1	+4
3	+1.3	+2	-1	0	-2	-3	+3	+6	-1	+1	-2	+9
4	-1.4	+3	+4	-7	-2	0	+2	+10	-3	+6	+3	+7
5	-0.9	0	0	-1	-1	-2	+4	+6	-2	-1	-2	+5
6	-0.9	-3	-3	-4	-2	0	+1	+7	-1	+3	0	+5
7	+3.0	+1	0	+1	+1	+4	+3	+9	+1	+7	+4	+1
8	-2.7	+2	0	0	-2	-1	-3	+6	+2	-1	+2	+3
9	+0.1	0	-6	-3	-5	-4	-4	+9	-4	+3	-3	0
90	-0.9	+2	+2	+5	+5	+2	+3	+8	+3	+3	+2	0
1	+1.2	+1	0	+2	0	-1	+1	...	-5	-5	-5	-2
2	-1.4	+2	+1	0	0	-4	-1	+4	0	-6	-3	+2
3	-1.6	+2	0	-2	0	+4	-2	+10	+4	+3	+3	+3
4	-0.7	+2	+1	+2	+5	+5	-2	...	+2	+5	0	0
5	+3.3	+5	+2	+1	+2	-2	-2	...	-3	-4	-7	-3
6	-0.2	0	-2	-1	-1	+2	+1	...	+5	+3	+1	+1
7	+0.7	-4	-5	+4	0	-1	±0	+6	+1	-1	-3	-1
8	+2.4	+2	+1	+4	+2	+1	0	+7	-1	0	0	-4
9	-1.3	+4	0	+3	+2	-1	0	+7	0	-1	-1	-3
1900	+2.3	+3	0	-3	-2	+2	0	+10	+2	+5	+5	+3
1	+4.0	+2	0	+1	+6	+4	+2	+8	+6	-2	-1	0
2	+2.9	-4	-5	+3	-1	-5	+3	+3	-3	-7	0	+4
3	+0.5	-7	-8	-5	-6	+3	-6	+5	-8	+1	-7	-6
4	+1.1	+1	-2	0	-4	-2	-2	+3	-4	-3	-6	-2
5	+1.9	-1	-1	+1	+2	-2	0	+4	+2	-4	0	-1
6	-2.5	+1	-2	+1	-4	-1	0	+4	-2	-3	-3	+2
7	-1.0	-2	-7	-1	-5	-2	-1	+3	-1	0	-4	-2
8	+1.9	+2	-2	0	-3	-2	-1	+2	-2	-3	-4	0
9	-1.1	+1	-3	0	-1	0	0	+6	0	+1	-1	0
1910	+1.5	-3	-6	-4	-3	+6	-2	+9	-1	+7	+3	-1

Station....	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	79°	70°	101°	76°	65°.5	60°.6	56°.1	67°.5	84°.6	52°.1	62°.6	67°.9
Year 1875	+2	...	...	...	+0.3	+0.7	...	...	...	...	...	...
6	-1	...	...	...	...	-1.7	...	...	...	...	...	...
7	-1	...	...	...	-0.1	-3.7	...	...	...	...	...	...
8	-1	...	+1	...	-2.5	-5.9	...	...	...	...	-4.6	...
9	-1	...	+3	...	+1.6	-2.5	...	...	...	...	-4.9	...
80	0	+5	+2	...	+1.9	-7.6	0.0	+2.3	...	-2.1	-5.5	...
1	+5	+1	+2	...	+2.5	-3.5	-2.9	-0.7	...	-2.1	-0.3	+0.3
2	0	0	-1	...	-0.8	-4.1	-1.3	-7.8	...	-1.6	+5.4	—
3	+3	+2	+5	...	+5.5	+0.4	+3.8	+9.3	...	-4.1	+2.8	+0.5
4	+1	+4	-3	...	+0.5	+4.7	+1.4	+1.9	...	—	-6.4	-6.7
5	-3	-1	-54	...	-0.1	-2.1	-2.6	-3.4	-0.8	-0.2	0.0	+1.5
6	+2	+4	+1	...	+3.3	+4.7	+1.3	-1.0	-1.2	—	+3.0	+4.3
7	+3	-1	+1	...	-1.9	+4.7	-2.4	-0.4	-2.7	-1.7	+0.7	+1.2
8	+2	-1	-1	-3	+7.2	+3.8	+2.1	+2.1	+3.2	+1.5	+2.5	-3.4
9	+4	+5	+1	+8	-0.3	+3.4	-0.2	+0.1	+4.3	-0.7	+4.7	-0.7
90	-2	0	-1	-2	+0.7	+3.3	+1.6	+1.0	+0.7	-2.5	+2.5	+2.4
1	-6	...	-3	-3	-2.1	+2.1	-0.9	-5.2	-2.6	+0.5	+0.2	-4.5
2	-1	-1	-1	-2	+0.5	+0.8	+0.1	+1.4	+2.2	-0.9	+7.1	+0.9
3	+1	-2	+4	0	-4.5	-1.1	-2.1	-4.0	+0.7	-4.1	+1.2	+2.9
4	-4	-1	-5	-7	+0.1	+2.2	+3.0	+1.9	-3.5	+2.9	+0.7	+0.8
5	-3	-3	+1	+1	+2.9	+1.1	+1.8	-1.4	+0.1	+0.7	+0.6	-0.6
6	+4	+6	+5	+4	-2.2	-1.4	-1.2	+2.4	-3.6	+2.3	+0.2	+1.6
7	-1	-2	-3	-3	+4.6	+5.9	+4.7	+4.8	+5.6	+2.3	+1.7	+2.0
8	+9	-1	0	+1	+1.1	+0.1	-1.7	+0.6	+0.1	-0.3	+1.3	+3.3
9	-1	-1	-1	+2	-0.4	+0.2	-1.0	-1.0	-2.7	+1.1	-2.5	—
1900	+8	+8	0	+5	+0.5	0.0	-0.1	+1.9	+2.4	-2.9	...	-1.9
1	-3	-7	-2	-1	-1.9	-1.8	-1.8	-4.4	-2.0	-0.2	...	+0.5
2	+3	-2	+1	+2	+3.4	+0.1	+0.8	+0.5	+0.9	-1.3	...	-0.8
3	+3	+4	0	+1	...	...	-1.7	-0.1	-1.3	+2.3	-2.4	-1.8
4	-1	+2	+1	+2	...	...	-1.8	-2.5	-5.3	+0.9	-1.9	...
5	+1	-3	-2	-2	...	...	-1.7	-0.1	-2.4	+0.1	-3.5	...
6	-4	-3	-2	—	...	...	...	...	...	+2.7	+0.3	...
7	-8	-2	-5	—	...	...	...	...	...	...	...	...
8	-7	-3	0	—	...	...	...	...	...	-2.5	...	+0.6
9	+3	-1	+1	—	...	...	...	...	...	...	...	...
1910	+4	+6	+2	—	+1.1	...	+1.2	+2.0	+0.7	+0.8	...	...

TEMPERATURE DEPARTURES FROM NORMALS—JUNE

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	89°.1	101°.5	99°.6	94°.7	106°.5	108°.0	15°.4	24°.3	15°.1	16°.7	25°.8	22°.6	14°.6	28°.8	17°.2	21°.1	20°.3	16°.5	19°.0	17°.3	17°.4	27°.8	34°.0
Year																							
1875	0.0	-0.6	-1.5	-0.5	+7.9	-1.3	+2.0	...	...	...	...	...	...	...	...	...	...	+3.5	...	...	...	+1.6	...
6	+0.4	+5.9	+3.4	+1.1	+1.3	-2.8	+2.2	+2.2	+1.8	-2.2	-0.5	+1.6	+1.1	...	+2.8	+3.2	+1.9	+2.5	+2.2	+1.4	0.7	+0.4	...
7	+2.5	+3.8	+2.9	+0.8	+0.1	-3.4	-1.8	+1.1	+4.4	+3.8	0.0	-1.9	+0.7	...	-0.8	+0.3	-1.0	-1.1	+0.8	+1.3	2.0	+3.2	...
8	+0.8	+6.9	+7.5	+2.9	+3.0	-2.8	+3.8	-0.2	+2.0	+0.2	+0.6	+2.3	+3.4	...	+3.5	+1.6	+2.3	+2.3	+1.4	0.0	-0.1	+1.8	...
9	-0.3	+0.4	-4.4	-1.6	-4.2	-2.0	+1.2	+1.9	+1.7	+2.1	+2.0	+0.4	-1.6	...	-1.5	+0.6	+0.6	-0.6	+0.9	+1.0	0.8	+0.9	...
80	+0.5	+0.9	-1.9	-0.8	+1.8	+0.8	+1.2	-0.8	+1.8	+0.6	+1.0	-0.3	0.0	...	-0.7	-0.1	+0.5	0.0	+0.5	+0.4	-0.4	+0.9	-0.3
1	+1.8	-3.4	-5.8	+1.7	+1.1	-0.9	-3.4	-0.3	-2.0	+1.0	-1.0	-0.6	-0.1	...	+0.4	+0.2	-1.6	-0.3	-1.2	-0.8	-0.6	+0.2	-0.7
2	+2.5	-4.1	-5.3	-0.5	+1.7	+3.1	+0.3	+1.3	-1.0	-0.5	+0.2	+0.6	+0.4	...	+0.5	+0.6	-0.3	+0.5	-0.2	-1.2	-1.7	-2.3	+0.2
3	+1.8	-1.5	-3.5	+1.0	+2.6	+3.2	+0.8	+1.6	-0.9	-1.3	+0.8	+1.0	+0.5	...	+1.6	+1.0	+0.1	+1.8	+1.1	+0.9	0.3	+0.2	+0.7
4	+1.0	-1.1	+0.8	+3.4	-2.8	-1.5	-0.2	+1.2	+1.0	-2.9	+0.5	-0.9	-1.5	+0.3	+0.6	-0.5	+0.1	+1.0	+0.2	-1.3	-3.0	+1.3	—
5	+0.8	+0.1	-5.0	-0.6	-0.4	-0.8	+0.4	...	...	+3.3	-0.2	-1.3	-0.3	-0.1	-0.7	+1.1	+2.1	-1.5	+2.6	+1.7	1.4	0.0	-2.9
6	+1.6	-0.9	-1.4	-1.7	-3.9	-0.8	+0.9	...	-2.0	-0.9	-0.6	+0.1	-2.6	+0.6	-2.2	+0.3	+1.1	-0.7	+0.7	-1.1	-1.5	+0.7	-0.4
7	-2.5	-0.8	-3.6	-2.5	-2.6	-2.4	-1.7	...	-1.0	+1.7	...	+1.2	+2.6	...	+0.1	+0.6	-1.8	-2.1	-2.9	-2.4	-0.9	-0.6	+1.5
8	-0.6	+3.0	-0.4	-0.4	-0.5	+0.2	-0.5	...	+1.5	+3.9	...	+1.3	+1.5	+0.1	-1.2	-0.2	-1.3	-2.5	-0.7	-0.9	0.0	+0.2	+0.5
9	-1.4	—	-0.5	-0.4	-0.5	—	+1.8	+0.6	+1.8	+1.4	...	+1.4	-0.3	+0.2	-1.1	-1.2	-0.2	-0.9	+0.1	+2.7	2.2	+0.6	+1.8
90	-0.8	—	-4.2	-2.2	-3.6	—	+0.4	+2.7	-1.1	-0.6	...	+2.5	+3.2	+1.0	+2.6	+0.8	-0.1	+1.6	-1.6	-1.7	-1.9	-0.2	-0.4
1	-1.4	+1.9	+9.9	+3.7	+2.2	+3.4	-1.3	-0.1	-1.2	-0.7	...	+0.4	+0.5	+0.8	+1.2	+3.2	+1.0	-0.1	+1.0	-1.0	-0.7	+0.4	+0.8
2	+0.8	-1.5	+0.5	-0.9	+0.4	-0.4	+0.3	+1.2	+0.8	+1.6	-0.9	-0.2	+2.5	+0.3	+1.7	+3.5	+2.9	+1.6	+3.3	+0.5	-0.3	-1.2	+3.0
3	-1.1	-6.9	-6.4	-3.0	-5.8	-2.7	+2.3	-1.4	+0.6	+1.8	+2.0	+3.1	0.0	+1.2	-0.8	-0.1	-0.9	-0.4	-1.1	+0.7	-0.4	-1.0	+1.9
4	-0.5	-2.8	-4.2	-0.3	-3.8	-0.2	+0.4	+0.5	-0.7	+0.8	+1.0	-0.5	-0.9	0.0	-0.5	-0.7	-3.0	-1.7	-2.9	-2.0	-1.6	-0.7	+1.4
5	+1.3	-3.4	-2.6	-0.5	-3.8	-2.1	+1.8	-1.1	-0.3	-0.8	-0.4	-1.9	-0.5	-0.3	+1.2	-0.6	-1.5	+1.7	-0.5	+1.3	-0.5	-2.1	+0.3
6	+2.0	-2.9	-2.2	-1.0	+0.3	+1.9	+0.2	+0.4	+3.2	+3.5	-1.3	+0.7	-0.2	-1.6	+0.1	-1.6	0.0	+2.7	+0.8	+2.2	0.2	-1.7	+0.2
7	-0.1	-0.8	+4.3	+1.1	-2.3	-2.0	+1.4	-0.1	+1.8	+1.2	-1.4	+0.6	+1.5	+0.4	+1.6	+1.7	+1.0	+1.9	+1.0	+1.5	0.9	-1.2	+1.6
8	0.0	-1.4	-0.9	-1.0	+1.2	+1.7	+0.8	+1.2	+1.0	+2.1	-1.5	...	+0.8	-1.4	+1.5	-1.4	-1.1	+0.8	-1.4	-0.3	-1.1	-1.5	+2.2
9	-3.0	-3.8	+0.1	-0.7	-0.6	-0.5	+0.6	+1.3	+0.1	+1.3	+1.7	...	+1.3	+1.2	-1.0	-0.1	-1.5	-2.2	-1.6	-2.3	-1.1	-0.9	-3.8
1900	0.0	-0.3	+6.0	+1.6	+3.3	+1.0	+0.2	...	+1.0	+4.7	-1.0	...	+0.3	-1.2	-1.3	-0.9	-1.6	-1.6	-0.5	+0.6	-0.1	-0.8	-3.0
1	-1.6	+6.7	+3.6	-0.3	+2.7	-0.3	+1.7	...	+0.7	+2.3	-2.8	...	+1.9	-4.9	+3.5	+0.5	+4.4	+5.4	+4.4	+1.3	+1.2	+0.1	+0.7
2	-2.8	+3.5	+5.9	+0.2	-1.5	-1.0	+1.5	...	-0.6	+0.9	+1.5	...	+1.8	-4.9	+2.3	+1.3	+1.4	+0.7	+0.8	-0.9	-1.4	-1.5	-0.3
3	-2.0	?	+4.4	+2.2	+3.7	+2.7	+1.1	-0.4	-0.9	-0.4	-1.0	+1.2	+1.5	+0.7	+2.8	+0.3	+1.8	+3.1	+1.6	-0.1	-0.9	-1.6	-2.5
4	0.0	-2.0	-1.8	-1.8	+1.7	+1.3	+1.2	+2.1	+2.2	+2.9	0.0	...	-0.1	-0.7	-2.5	-0.9	-2.1	-3.1	-0.7	-1.4	+0.3	-2.8	+1.8
5	-0.3	+5.9	+6.9	+1.4	+2.4	+1.0	+1.2	-0.2	-0.9	-0.6	-0.9	...	0.0	+1.1	-0.2	+0.3	+2.6	+2.4	+1.2	+2.2	+1.1	-1.4	...
6	-0.8	0.0	-2.6	-0.3	-0.8	-1.4	+0.7	...	+0.5	+1.1	+1.3	...	+2.7	+0.2	+2.7	+0.7	+2.2	+1.3	+1.4	-0.8	-0.9	-0.8	...
7	-3.0	-1.1	+1.4	+0.7	-1.5	-3.1	+2.0	+1.4	-0.4	-0.7	-2.9	...	+0.1	-1.0	+1.2	+1.6	+0.1	0.0	+0.3	-0.9	+0.4	-1.8	+4.0
8	-0.3	+3.3	+2.0	+2.7	+2.6	+1.9	+2.1	+0.9	+0.9	+0.6	-1.6	+0.1	+0.2	+1.2	0.0	+1.2	+0.8	-1.0	0.0	+0.2	+2.0	-2.0	+2.4
9	-1.3	-7.6	-2.6	+0.8	-1.1	-1.1	...	...	...	...	...	...	+2.5	...	+1.1	-1.2	-1.3	-0.4	-0.2	-0.5	-1.0	-1.2	-0.1
1910	-2.4	-2.1	-4.3	-0.3	-0.8	-1.2	...	...	...	...	...	...	-0.3	...	+0.1	+0.7	+0.2	+0.9	+1.2	...	+0.5	-1.9	+1.4
Normals, 1877-1906							16.0	...	15.6	17.9	...	...	14.7	...	17.6	21.4	20.5	19.2	19.3	17.3	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—JULY

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne
Normal ...	10°.1 C	82° F	85°	87°	88°	83°	93°	85°	90°	82°	82°
Year											
1875........	+0.2	−3	−2	...	−3	−3	+7	−3	−3	0	−6
6........	+1.2	+1	+3	...	−1	0	+1	−1	+2	+1	+4
7........	+1.0	−1	+1	...	−2	0	−1	−1	+1	−3	+3
8........	−0.5	0	+6	...	+2	−1	−1	−1	+2	+3	+1
9........	+0.5	−2	+3	0	+3	0	+1	+1	+3	−1	+4
80........	+0.1	+1	0	+1	−1	−1	−4	+1	−2	−1	0
1........	−2.0	−1	+3	+3	+5	−1	+4	+1	0	+2	+4
2........	−0.8	0	−1	−3	−3	−8	−1	−4	−2	−5	0
3........	−0.1	−1	−1	+2	−1	−4	+4	−2	−2	−2	−1
4........	−0.1	−3	0	−2	−2	−6	+6	−3	−1	−7	0
5........	−2.2	+2	+2	0	+1	0	+3	0	−1	−1	−1
6........	+0.3	+1	+1	−1	+1	+2	0	+5	+2	+8	+3
7........	+0.6	+4	+5	−1	+4	+3	+2	+1	+3	+1	−1
8........	+2.8	0	−3	+1	+1	0	−1	+2	+2	−1	+2
9........	−0.7	−1	−1	0	−2	−1	−1	−1	0	−2	+1
90........	+1.1	0	−1	0	+2	0	0	+1	+6	+2	+2
1........	−1.2	−4	−5	−3	−4	−5	−3	−5	−6	−6	−4
2........	+0.3	+2	−2	−3	−3	−1	−3	0	0	−2	−2
3........	+1.2	+1	0	+2	+1	+3	+1	+1	+3	+1	+1
4........	−0.3	+3	+2	−2	+1	+6	−3	...	+2	+8	−1
5........	+2.0	−2	−4	−2	−3	−1	−3	...	−6	−2	−7
6........	+3.5	+2	−3	−7	0	−1	−2	...	−1	−1	−3
7........	−1.9	+1	0	+1	+1	+1	+3	+3	+2	0	−2
8........	−1.5	+4	+1	−1	−2	+1	−2	0	−2	0	−2
9........	+4.3	+1	+1	+1	−1	0	+1	−1	−4	0	−2
1900........	+2.5	+4	+2	0	−1	−2	−3	0	0	+2	−3
1........	+0.6	+4	+3	+3	+10	+7	+2	+11	+6	+2	+5
2........	−0.8	−3	−1	+3	+1	−1	−4	−1	−1	−1	−4
3........	+0.1	−1	−2	0	+1	−3	−2	−2	+3	−2	−1
4........	+1.9	0	−4	−1	−4	−3	−3	−3	−3	−4	−6
5........	−1.6	+1	−2	−1	−5	−3	−5	−4	−4	−4	−5
6........	+0.1	0	−3	−3	−3	−1	−3	−3	−5	−2	−6
7........	−0.5	+1	−3	+3	−1	−1	0	−2	0	−2	−2
8........	+0.5	+3	0	0	−3	−1	−2	−1	−3	+4	−4
9........	−0.6	−1	−5	−2	−3	0	+1	−3	+1	−1	0
1910........	−0.7	+3	−1	−3	−3	+5	−2	+1	+2	+5	+2

Station....	El Paso	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	95°	88°	79°	106°	84°	64°.3	59°.7	55°.1	66°.7	83°.2	50°.6	63°.2	67°.8
Year													
1875........	...	−2	...	...	...	−0.1	+1.3	...	...	...	...	...	...
6........	...	+2	...	...	...	−3.2	—	...	...	...	...	...	...
7........	...	+2	...	...	...	+3.3	+0.1	...	...	...	...	...	...
8........	...	+2	...	+4	...	+2.3	−1.2	...	...	...	...	−6.0	...
9........	...	+2	...	+3	...	−2.1	−5.7	...	...	...	...	−5.8	...
80........	−2	−2	+1	−1	...	+1.8	−1.7	+1.9	+1.3	...	−1.2	−3.2	...
1........	−1	−1	0	0	...	−0.5	−2.0	+0.9	+1.9	...	0.0	−1.1	−0.8
2........	+6	0	−1	+2	...	+0.2	−3.2	−0.1	−2.9	...	−0.6	+0.5	−1.1
3........	+5	−1	−2	+1	...	+3.0	−2.3	+0.9	+5.6	...	+0.8	+2.3	+2.4
4........	+11	−1	−5	+1	...	−0.5	+2.0	+1.8	−3.1	...	—	−4.0	−4.7
5........	+7	+1	−1	...	...	+3.6	+1.8	+1.4	+3.0	+3.1	+2.3	+3.8	+1.6
6........	+7	+3	+6	+1	...	+5.6	+2.0	+0.2	+3.1	+5.2	—	−5.6	−6.4
7........	0	0	0	0	...	−0.1	+7.1	−1.0	+2.0	−0.2	−0.8	+2.1	−4.0
8........	0	+2	+2	+1	+1	+5.6	+2.7	+0.3	+1.9	+2.7	+0.2	+0.2	−3.1
9........	+1	+4	+1	0	+4	+1.7	+4.3	+1.0	−1.3	+1.4	−2.0	+4.1	+1.0
90........	0	+3	+5	0	0	+1.3	−0.8	−1.5	−1.0	+2.1	−3.7	+1.0	−3.7
1........	+2	−1	...	+2	−1	+1.4	+0.7	−0.4	−2.4	−1.3	−1.0	−1.7	+2.3
2........	0	0	−1	0	−2	+1.8	+0.1	+0.2	+2.4	+3.9	−1.0	+8.1	+1.0
3........	−2	−1	+3	−2	−1	−0.1	+1.0	+1.1	+3.8	+5.8	−0.1	−0.7	+0.5
4........	−1	0	+3	−1	0	−0.7	−0.3	−0.4	0.0	−2.6	−0.4	+2.7	+1.7
5........	−4	−3	−1	−1	−2	+0.5	+2.2	−1.6	−5.3	−4.8	+0.3	+4.7	+2.3
6........	−4	−2	+1	−1	+3	−3.3	−3.1	−1.6	0.0	−3.9	−1.1	+2.8	+2.6
7........	+1	−3	−4	−1	−2	+2.1	+3.8	+4.4	+2.3	+2.3	+3.2	+2.3	+3.2
8........	−4	+1	−1	−1	+2	+3.3	+0.7	−0.6	+1.1	−1.0	+2.9	−0.7	+2.6
9........	−3	+1	+2	−1	+2	+0.6	+0.1	−1.1	−3.4	−4.8	+2.0	−5.0	—
1900........	−2	0	+1	−1	+1	−2.8	−1.8	−2.0	−4.0	−2.8	−0.6	...	+1.0
1........	−2	+6	+5	−1	+1	−3.2	−1.6	−2.7	−5.0	−4.3	−1.4	...	+0.1
2........	−6	−3	−5	−4	−2	+4.7	+2.6	+1.8	+1.8	+1.1	−0.5	...	+3.6
3........	+1	−2	−4	−2	−4	...	...	−2.2	−1.0	+2.4	+0.4	+0.1	−1.2
4........	−1	−1	0	−4	−2	...	...	−2.3	−2.0	+0.5	−0.2	+0.7	...
5........	−4	+1	+2	−2	+3	...	...	−1.8	−2.6	−0.1	0.0	+1.6	...
6........	−5	0	+5	−2	—	...	...	...	...	...	−0.6	−4.0	...
7........	−2	−1	−1	−3	—	...	...	...	...	...	...	...	...
8........	−6	−1	+4	0	—	...	...	...	...	...	+0.4	...	−0.4
9........	−2	−1	0	0	—	...	...	...	...	...	...	...	...
1910........	0	+2	+4	0	—	−1.6	...	−1.8	−0.8	+4.3	+1.0	...	...

TEMPERATURE DEPARTURES FROM NORMALS—JULY

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent
Normal ...	89°.8	92°.1	88°.2	91°.2	99°.3	103°.4	18°.4	26°.1	18°.6	19°.6	27°.5
Year											
1875........	+ 0.7	+0.1	−1.9	+0.2	+5.3	+6.5	+1.6	...	...	...	...
6........	+ 0.1	+1.4	−0.5	+0.6	−4.7	−0.6	+0.1	+1.9	+1.3	0.0	+0.3
7........	+ 1.0	+4.6	+3.2	+4.4	+6.4	+1.0	−0.5	+2.0	+0.2	+0.4	+1.1
8........	+ 1.0	+3.9	+0.8	+0.6	−0.7	−2.2	+1.6	+1.0	+3.1	+3.0	+3.0
9........	− 0.6	−2.0	+0.9	−0.2	+4.7	+1.4	+1.2	+0.1	+1.9	+2.3	+1.8
80........	0.0	−2.3	0.0	−1.0	−3.9	−1.0	+1.8	+1.9	−1.5	−1.0	0.0
1........	+ 2.8	−0.1	−1.9	+2.8	−3.2	+0.6	−0.2	+1.6	+0.1	+1.0	+0.4
2........	+ 2.5	+0.4	−3.5	−1.6	−2.5	−4.6	+1.2	+0.5	−0.6	−1.1	−1.0
3........	+ 2.8	+0.4	−1.1	+0.9	+3.2	0.0	+0.9	−1.1	−0.8	−1.3	−0.4
4........	+ 2.5	−0.6	−3.6	+1.0	−0.8	+1.3	−0.1	−1.1	−0.6	0.0	−0.4
5........	+ 0.4	−0.9	+0.3	+0.1	+1.3	+2.7	+2.4	...	...	−1.4	−2.1
6........	− 0.2	−2.9	0.0	−0.4	−5.2	−1.3	+0.5	...	−2.1	+0.5	+0.6
7........	+ 2.0	−0.2	−4.2	−3.8	+0.4	+1.2	+2.1	...	+1.3	+0.8	...
8........	+ 0.4	−2.9	−1.0	−0.9	+0.2	+3.3	−0.3	...	−0.6	+1.5	...
9........	− 0.1	—	+1.4	+0.3	−2.4	—	+2.3	−1.0	+0.4	−0.9	...
90........	− 1.3	—	−3.4	−1.5	−5.5	—	+1.6	−2.2	−2.7	0.0	...
1........	+ 2.1	+4.1	+0.2	−0.7	+4.6	+5.3	+1.8	−1.0	−0.7	+0.6	...
2........	+ 0.4	+0.1	−0.1	−1.3	−0.3	−0.3	−0.9	−1.2	−2.1	+1.7	−0.5
3........	− 1.2	−3.3	+1.4	−1.9	−6.1	−3.8	+1.3	−0.6	−0.4	0.0	+0.2
4........	+ 0.1	−2.4	−1.7	−0.3	−6.3	−5.8	+0.8	−0.4	−0.8	+0.7	+0.4
5........	− 1.8	−0.2	+1.5	−1.8	+3.0	+0.1	−0.8	−1.1	−0.6	+3.9	+0.7
6........	+ 0.7	+0.3	+1.3	−0.9	+2.8	+1.1	+1.4	−1.3	−0.2	+1.8	−0.2
7........	− 2.1	+1.5	+5.1	+1.9	+2.6	−0.2	+2.4	−0.4	0.0	+1.2	+0.7
8........	−10.9	−2.3	−1.5	−0.5	−5.4	−2.2	−0.7	−0.2	−2.5	+1.2	−0.2
9........	−11.0	−5.6	+2.4	+1.9	+2.7	+1.5	+1.1	−0.2	−0.9	−3.4	−0.3
1900........	−11.8	+1.1	+4.6	+0.5	+4.5	+2.7	+0.4	...	+1.1	+1.9	+0.6
1........	− 0.1	+4.4	+0.2	+0.6	+0.3	+2.1	+1.3	...	−1.1	+2.4	−0.3
2........	− 1.2	−0.2	+2.5	+0.1	+2.1	−0.4	−0.5	...	−2.4	+0.3	−0.6
3........	− 0.7	−1.1	+1.0	−1.1	+0.1	−0.6	+1.4	+1.6	+0.3	−0.5	−1.0
4........	− 1.5	−2.8	+0.8	−0.6	+3.1	+1.7	+0.3	−0.6	−2.2	+1.0	−0.5
5........	− 1.1	−0.1	+0.4	+2.8	+1.7	+1.1	+1.9	+0.3	+0.7	+1.6	−0.6
6........	+ 0.8	−0.5	−1.8	+0.5	+3.4	−0.5	+0.2	...	−2.9	−2.0	−0.9
7........	− 2.0	+5.4	+2.2	−0.7	+4.6	+3.2	+2.1	−0.3	−3.4	−2.3	−0.3
8........	− 2.1	+2.0	−1.9	−1.3	−2.8	−3.8	+1.1	−0.8	+0.5	−0.7	+0.4
9........	− 1.5	−1.8	−2.4	−1.4	−2.6	−4.6	...	...	...	...	...
1910........	− 3.4	+2.6	−0.2	+0.1	−1.1	−6.3	...	...	...	...	...
Normals, 1877-1906							19.3	...	18.1	20.2	...

Station....	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	24°.4	17°.5	30°.8	19°.6	24°.3	22°.8	18°.4	21°.7	18°.6	19°.6	28°.8	38°.1
Year												
1875........	...	...	...	...	...	...	...	...	...	...	+0.8	...
6........	+1.8	+1.2	...	+1.3	+0.3	−0.3	+1.2	+0.5	+0.3	0.1	−1.2	...
7........	+1.0	+2.2	...	+4.1	+2.2	0.0	+2.4	−1.5	+0.4	−0.4	+3.3	...
8........	+2.2	+1.4	...	−0.7	+0.2	−2.7	−1.8	−3.0	−2.1	−1.2	+0.3	...
9........	+1.6	+1.2	...	−0.1	+2.8	+0.4	−1.1	−1.5	−1.7	−2.5	+0.6	+1.2
80........	+1.7	+1.0	...	+0.8	+1.4	+0.1	+1.8	+0.3	+1.7	1.2	+0.9	+0.3
1........	−1.6	−0.2	...	+0.1	−0.8	−0.8	+1.0	−0.7	+0.6	1.3	−0.2	+0.8
2........	−0.9	−0.4	...	+1.5	+2.7	+2.6	+3.0	+3.3	+1.9	−0.1	+0.1	−0.6
3........	+1.0	−0.5	...	+0.7	+2.3	+2.9	+1.0	+2.3	+0.6	−0.5	−0.5	+0.1
4........	−1.1	−0.7	−1.7	+0.1	−0.4	+0.3	−0.4	+0.4	+1.3	0.5	−1.5	−2.9
5........	−2.9	−1.3	−0.4	+2.6	+1.2	+2.5	+4.4	+2.7	+1.0	0.3	+0.1	−2.6
6........	+1.7	−0.7	+0.1	−0.4	−1.8	−0.1	0.0	−2.6	−0.8	−0.3	−0.9	−0.6
7........	−0.7	−0.5	...	+0.2	−1.9	−1.5	+0.5	−1.2	+1.2	2.3	−0.4	+0.1
8........	+3.3	+2.7	+0.8	+1.5	−0.3	−0.7	0.0	−1.7	−1.9	−1.9	+2.2	+1.8
9........	+0.9	−0.9	+1.3	+0.6	+1.0	+1.5	+0.6	+1.7	−0.3	−0.4	+1.5	+1.6
90........	+3.3	+3.9	+1.0	+4.4	+0.1	+3.4	+3.0	+0.9	+0.3	−1.0	+1.1	+0.5
1........	+0.9	−0.1	+0.9	+2.1	0.0	+2.3	+2.7	+1.2	+0.4	−1.2	+0.3	+1.0
2........	+2.5	+1.8	+1.0	+1.7	+1.3	+0.3	−0.1	−0.9	−0.6	−1.2	−1.0	+1.6
3........	+2.7	+0.3	0.0	+1.3	−0.1	−0.7	+1.3	−1.1	+1.0	−0.3	−0.5	+0.7
4........	−0.4	−2.3	−0.8	−1.7	−0.8	−1.6	−0.7	+0.8	+1.9	0.7	−1.1	+0.6
5........	+2.2	+0.2	−1.2	+0.3	−0.7	+0.6	+1.3	+0.6	+1.7	0.7	−0.6	+1.4
6........	−0.7	0.0	−0.7	−0.9	−1.6	−2.1	+1.2	−0.7	+2.1	−0.1	−1.2	—
7........	+1.1	0.0	...	−0.5	+0.6	+1.6	+2.8	+1.2	+0.2	−0.5	−0.6	−0.7
8........	...	+1.9	+1.4	+3.6	+2.3	−0.1	+2.1	−1.0	−2.7	−1.7	−1.4	+1.4
9........	...	−1.1	+1.1	+0.3	+2.3	−0.3	+1.9	−0.2	+0.6	−0.4	−1.5	−2.2
1900........	...	−0.7	−1.6	−1.5	−0.5	−0.1	+0.1	+1.4	+1.5	0.8	−0.8	−3.0
1........	...	+0.6	+0.4	0.0	+0.6	0.0	+0.4	+0.7	+1.7	+0.9	−0.1	−0.5
2........	...	+3.2	−0.1	+2.0	−0.5	−0.9	−1.1	−2.4	−2.4	−1.8	−1.6	+0.8
3........	+2.9	+0.5	+0.6	+1.8	−0.6	+0.9	+1.5	+0.2	−0.5	−1.1	−2.5	...
4........	...	0.0	+0.7	−2.4	−0.7	−1.6	−2.5	−0.7	+0.2	+1.6	−1.9	+0.6
5........	...	−2.2	+0.9	−1.9	−0.1	+0.5	−0.7	+0.5	+0.1	+1.3	−0.7	...
6........	...	+2.4	+0.2	+3.8	−1.1	+1.4	+1.4	−0.6	+1.1	−0.6	−1.0	+1.1
7........	...	+2.5	+2.7	+3.5	+0.4	+0.4	+0.8	−0.8	−1.7	−2.3	−1.5	+2.2
8........	−0.5	−3.8	+0.6	−1.0	−1.3	−0.9	−0.6	−0.7	+0.6	−0.5	−2.0	+2.6
9........	...	+0.7	...	−0.8	+2.0	−0.6	−0.5	−0.2	−1.2	−2.1	−1.4	−0.2
1910........	...	+1.1	...	+1.8	+1.5	0.0	+1.1	−0.6	...	−2.0	−1.5	+3.6
Normals, 1877-1906	...	17.9	...	20.4	24.6	23.1	19.2	21.6	18.9	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—AUGUST

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	12°.4C	80° F	83°	85°	86°	80°	92°	81°	89°	81°	80°	93°	87°	79°	104°	84°	70°.0	64°.0	58°.6	75°.2	89°.6	52°.2	68°.0	69°.9
Year																								
1875........	0.0	−2	−2	...	−5	−3	0	−1	−4	−2	−3	...	0	...	...	...	+0.9	−0.3	...	...	...	...	...	...
6........	−1.4	+3	+3	...	0	+1	0	+2	+1	−1	+1	...	−2	...	...	...	−3.8	−1.5	...	...	...	...	...	...
7........	−0.9	0	+2	...	−2	+1	+1	+2	0	−1	+2	...	+1	...	...	...	+4.2	+2.7	...	...	...	...	...	...
8........	−0.8	−1	+3	...	+1	0	+1	+4	+3	0	+2	...	+3	...	+2	...	+2.2	−0.1	...	...	...	...	−8.8	...
9........	−0.1	−4	−1	−4	−1	+1	−5	+4	0	−1	+2	...	0	...	+5	...	−0.8	−1.8	...	...	...	...	−5.0	...
80........	+1.5	−1	+3	−1	+5	0	−3	+6	−3	−4	0	−2	−3	−2	+1	...	+6.9	+0.4	+5.4	+8.3	...	+1.2	−3.8	...
1........	−0.6	+1	+6	+2	+9	+2	+8	+9	+3	+1	+3	0	−2	−2	−1	...	+0.3	−2.5	+0.1	+0.9	...	−1.2	−1.4	−1.9
2........	+0.5	+1	−1	−2	−1	−2	−2	+4	−1	+3	+5	+1	0	+2	+1	...	+1.0	−2.4	−1.3	+0.3	...	−0.1	+1.1	+0.3
3........	−0.3	−2	−2	0	−2	−4	+3	−1	−6	−2	+2	+3	0	−1	+2	...	+2.1	−0.9	+1.3	+2.6	...	−1.8	−6.9	−5.9
4........	+3.8	+1	+3	−2	−3	−3	+2	−1	−7	−3	−5	+5	−3	0	−1	...	+2.9	+2.2	+2.7	+4.5	...	—	+3.0	+3.1
5........	−0.4	−3	−1	0	−2	−7	+1	−5	−4	−6	−3	+4	0	−2	...	...	+6.1	+3.1	+3.4	+4.7	+1.5	+0.1	0.0	+0.5
6........	+0.1	+2	+1	+1	+3	+2	+4	−5	...	+2	...	+5	+2	+5	−2	...	+0.4	+0.7	−1.3	−0.9	−2.4	—	−1.6	−2.1
7........	+3.6	−2	−1	0	+2	−1	+2	0	−2	−5	−2	0	−1	−4	+1	...	−0.4	+5.1	+0.9	−2.5	−2.8	−0.8	−2.7	−4.6
8........	+1.6	+1	+1	+2	−3	−3	−1	+1	−3	−4	−3	+1	+1	+1	+3	+1	+5.3	+1.6	−1.2	−0.3	+3.2	−1.6	+3.2	−1.1
9........	−1.8	0	−3	−3	−1	+1	−2	+4	0	+4	+3	+3	+3	+3	+3	+3	+0.2	+1.1	−1.6	−2.9	+2.5	−1.7	+3.2	+2.9
90........	−1.4	−1	−3	−1	−3	−3	−1	0	0	+1	−2	−2	−2	0	−2	−1	−1.2	−2.3	−1.7	−0.1	+1.0	−1.4	+2.9	−1.0
1........	0.0	0	−2	0	−3	−1	−3	...	−2	−2	−1	0	0	...	+1	+1	−1.1	+1.1	+2.1	−5.9	−4.2	+0.4	+0.1	−4.1
2........	−2.3	0	+1	−1	0	0	−3	+2	+1	+1	+1	−2	+2	+1	+2	0	−1.6	+0.6	−0.5	+9.1	+6.9	+1.6	+7.5	−1.0
3........	−1.9	+2	−1	+1	0	+2	−1	+2	−3	+2	−2	−5	−1	+2	0	0	−1.0	+1.9	+1.2	−0.8	−1.0	−0.3	+1.5	+1.1
4........	−0.7	−1	+1	−1	+2	+5	−4	...	0	+6	+1	−5	+1	+4	−1	−1	−2.1	−1.5	−2.3	−1.6	+1.5	+0.6	+2.5	+5.5
5........	+1.5	+2	+2	0	0	+4	0	...	−1	+3	−2	−3	+1	0	0	−1	+3.5	+4.2	+0.9	+0.3	−1.2	+3.2	+5.1	+6.1
6........	+4.0	+2	−2	+5	+3	+2	+4	...	+4	+1	0	−1	−1	−1	0	−1	−2.5	−1.4	−1.9	−4.3	−4.0	+1.8	+2.0	−0.1
7........	−1.8	−1	−3	−1	0	−4	+2	−1	−1	−2	−2	−4	+1	+3	+1	+3	−2.5	−1.2	+1.0	−1.8	+2.2	−0.6	+3.6	+3.5
8........	−2.1	+2	0	−1	0	+1	−1	+4	+2	+1	+3	−3	+3	+3	−1	+4	+7.4	+1.0	+0.3	+0.8	+2.5	+2.5	−1.0	+6.0
9........	+0.6	+2	+2	+4	+4	+3	+6	+3	+5	−1	0	+1	−5	−7	−2	−8	−2.5	+1.7	0.0	−5.8	−6.5	+0.4	−1.3	—
1900........	−0.9	+5	+6	+6	+6	+8	−1	+7	+4	+4	+3	+2	−1	−4	−3	−5	−2.2	−3.0	−3.5	+1.3	+4.0	−0.2	—	−3.7
1........	−0.3	+2	+1	−1	+4	+4	+1	+6	+3	+2	+1	+2	+1	+2	0	+1	−1.8	+0.3	−1.9	−5.7	−2.3	+0.8	—	+2.1
2........	−3.3	−2	−3	+4	−2	−3	+3	−1	+5	−3	0	−2	−1	−2	−1	−2	−1.3	+0.1	−2.0	−4.5	−1.4	+1.2	—	−2.4
3........	−1.1	−7	−2	+1	−2	−6	−1	−1	0	−5	+1	−1	+3	−1	0	−1	...	...	−0.8	−1.2	+1.2	+0.3	−0.2	−1.4
4........	−0.8	−1	−3	−2	−3	−2	−2	+2	−2	−3	−1	−3	−1	+3	−3	0	...	...	−1.4	−4.1	−2.1	+1.2	−0.9	...
5........	+0.3	−2	−2	−1	0	+1	0	+5	+2	+1	+1	0	+2	+3	0	+1	...	...	−3.3	−7.0	−0.3	−2.0	−2.7	...
6........	−0.8	+3	+1	+1	0	+2	−1	+3	−2	−2	−1	−6	−2	−1	−2	—	...	...	...	...	...	0.0	−1.8	...
7........	−2.3	0	−5	+2	−2	−2	+2	+3	−1	+1	−1	−2	−4	−4	−2	—	...	...	...	...	...	...	...	...
8........	−1.5	−1	−2	+1	0	0	−2	−1	−1	−2	−4	−4	−4	−3	0	—	...	...	...	...	...	−0.7	...	−0.2
9........	−0.9	−1	−2	+1	+4	+5	+2	+7	+4	+4	+2	−2	0	+3	−4	—	...	...	...	...	...	...	...	...
1910........	−0.2	−1	0	+1	−3	+2	−1	0	−2	−3	0	0	0	−3	+3	—	+0.6	...	+1.1	−1.6	−0.3	+1.4	...	...

TEMPERATURE DEPARTURES FROM NORMALS—AUGUST

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	89°.1	89°.9	87°.1	91°.0	97°.1	101°.4	15°.5	24°.7	16°.1	16°.7	25°.1	22°.6	14°.8	29°.5	17°.4	24°.3	22°.0	17°.3	20°.2	17°.9	18°.8	28°.3	36°.9
Year																							
1875........	−1.4	−0.5	−0.8	+1.5	+0.7	+4.0	+1.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.0	...
6........	+3.2	+0.1	−0.1	+1.8	−1.5	+3.1	+0.2	+1.7	+0.2	−0.3	...	+0.1	+0.8	...	+0.4	+1.5	−0.7	−0.4	+1.4	+0.4	0.9	−1.3	...
7........	+3.6	+5.9	+1.2	+3.3	+9.7	+4.7	+0.5	0.0	+2.4	+1.3	+0.6	+0.3	+0.7	...	−0.8	+1.6	−1.2	−2.2	+1.4	+0.4	2.2	+4.4	...
8........	+1.4	+1.4	−0.1	−0.3	−4.9	−4.5	+2.2	−0.4	+2.0	+2.1	+2.9	−0.3	−0.9	...	−1.1	−0.6	−2.2	−1.6	−0.2	+0.5	0.1	+2.2	...
9........	+0.9	−0.4	−2.8	−2.9	−1.9	−1.7	+1.8	+0.6	−0.4	−2.0	+1.8	0.0	−1.5	...	−0.7	−0.9	−2.6	−2.1	−1.8	−0.4	0.8	+0.1	+1.4
80........	+2.5	+1.4	+3.3	+0.2	−4.2	+1.3	+1.1	+0.6	−1.0	+0.1	+0.8	+0.6	+1.4	...	+1.3	+0.4	−0.4	+0.9	−0.6	0.0	−1.5	0.0	−0.2
1........	+1.9	−0.5	−0.4	+1.9	−4.0	+0.2	−0.5	+0.2	...	+0.9	+0.6	+0.6	+2.6	...	+0.4	+0.4	−0.8	−1.0	−0.7	−1.2	0.5	+0.5	+0.9
2........	−0.5	−0.7	+2.6	+1.1	−0.5	−2.1	+0.9	−0.2	+0.4	+1.0	+1.1	+0.9	+0.3	...	+2.7	+2.5	+0.2	+2.3	−0.4	−1.0	−2.2	−0.3	+0.5
3........	+1.0	+3.7	+4.5	+0.2	+7.2	+3.7	+1.1	−0.2	−1.9	−1.5	+1.2	+2.5	−1.0	...	−1.6	+0.5	+0.4	−1.9	+0.3	−1.1	−0.3	−0.7	−2.5
4........	+1.1	−0.3	−1.8	+2.0	−1.3	−0.4	−1.0	−1.6	−2.6	−2.4	−0.5	−1.9	−3.3	−0.8	−2.8	−1.9	−2.8	−4.3	−2.4	−1.4	−0.8	−1.0	−1.5
5........	+1.6	−2.2	−0.1	+1.6	+1.4	+1.8	+0.8	...	...	−1.2	+1.4	−0.5	−2.7	+1.4	−1.5	−1.4	−2.8	−2.5	−1.8	−2.9	−1.5	−0.4	−0.1
6........	−0.7	−0.1	+2.9	−1.8	−0.7	+1.4	−2.0	...	−0.5	+0.4	+0.9	+0.3	0.0	+0.8	−0.5	−1.1	−0.2	−0.8	−0.2	+0.3	0.6	−0.5	−1.9
7........	−0.1	−1.2	−2.5	−2.1	−5.5	+0.9	−0.4	...	−2.2	−1.6	...	+0.1	+0.2	...	+0.8	−1.0	−0.6	−1.4	−0.7	−1.6	−0.3	−0.5	+0.8
8........	+1.2	−1.8	−0.3	−0.3	−0.6	+2.7	+0.5	...	+0.6	+0.9	...	+1.4	+0.4	+0.4	+0.4	+0.3	−1.7	−1.2	−1.1	−1.0	−0.8	+0.5	−0.3
9........	+1.8	—	−0.7	−0.1	−1.4	—	+1.4	−0.1	−1.1	+0.6	...	+2.0	+1.2	0.0	+0.7	−0.2	0.0	−1.3	+0.6	−1.1	−1.0	+0.3	+2.9
90........	−1.4	—	−0.8	−1.3	−5.9	—	+0.5	+0.4	−1.5	−0.5	...	+0.2	0.0	−0.9	+2.0	+0.3	+1.7	+2.3	+3.4	+3.0	1.7	+1.5	+1.4
1........	+1.2	−0.3	−1.1	+0.4	−0.8	+1.5	+1.6	−0.2	−0.6	+1.7	...	+1.0	−0.2	+1.0	0.0	+1.0	+1.1	−1.1	+0.1	−1.0	−1.5	+0.5	+9.2
2........	−1.2	−1.3	−1.0	−3.9	−6.1	−4.6	0.0	−0.8	−1.4	+2.0	−0.3	+0.7	+0.1	+0.1	−0.2	+0.3	−0.6	−0.7	+0.5	+2.8	2.3	−1.2	+1.5
3........	−1.6	+0.4	−1.3	−4.1	+2.6	+0.8	−0.4	−0.4	−1.2	+0.7	−0.3	+0.4	−0.2	−0.8	+0.6	+0.4	−0.5	+0.1	−0.5	−0.5	0.2	−1.1	+0.4
4........	−1.8	−3.0	−1.2	−0.6	−1.7	−0.3	0.0	−0.4	+1.3	+0.3	−0.5	+1.7	+1.3	+0.1	+2.7	+1.4	−1.0	+0.3	+0.2	−0.6	−0.6	−1.2	+0.6
5........	−1.3	0.0	+0.3	−1.6	−1.9	−2.2	−1.0	−1.1	−1.7	+1.1	−1.1	+1.4	+1.3	−1.9	+0.2	−0.8	0.0	−1.0	+0.7	+0.3	−0.7	−1.4	+0.2
6........	−0.1	+1.9	−2.8	−0.7	+0.4	+0.3	+0.3	−0.5	−0.8	+0.1	−0.2	+2.1	+1.0	+0.4	+1.8	+1.2	+0.3	+1.0	+1.3	−0.5	−2.4	−0.2	—
7........	−0.4	−1.2	−0.2	+1.0	−4.7	−5.2	+1.7	+0.8	+0.3	0.0	+0.1	+2.4	−0.5	...	+0.2	+0.2	+0.2	+2.8	+1.6	+1.4	0.1	−1.8	+1.1
8........	−0.9	−3.1	−3.2	+1.1	+2.2	+1.6	+1.9	−0.4	−0.1	+0.2	−1.5	...	+0.1	+0.2	+1.4	−0.5	−2.0	+1.2	+0.4	+0.7	0.6	−2.4	+1.3
9........	−0.9	+0.7	+5.4	+2.8	+5.6	+0.2	−1.0	+0.3	−1.1	+2.1	+1.6	...	+0.5	+2.4	−1.4	+1.0	−2.2	−3.6	−1.9	−1.4	−0.4	−1.6	−2.0
1900........	+1.2	+0.9	−0.4	−1.1	−0.4	+1.4	+1.3	...	+0.6	+1.7	−0.2	...	+0.6	−1.4	+0.7	−1.9	0.0	+1.3	+2.8	+0.5	−0.7	−0.7	−2.2
1........	−0.8	−0.2	−2.5	+0.5	+0.5	+0.1	+0.7	...	0.0	+1.5	−0.7	...	−1.5	+0.1	+1.4	+0.7	+1.9	+2.3	+0.9	+0.4	+0.2	−0.5	−1.0
2........	−1.8	+1.9	+4.0	+3.5	+2.7	+0.9	−2.2	...	−2.2	+0.9	+0.7	...	+1.8	+1.1	+0.6	−0.3	+0.7	−2.5	−0.3	−1.9	−1.0	−1.4	+0.1
3........	−2.3	+1.0	+0.6	−0.9	+0.3	−3.5	+0.6	+1.4	−2.1	−0.6	+0.3	+2.3	+1.9	+0.2	+2.1	−0.7	−2.0	−0.4	+0.5	−1.3	−0.7	−1.7	...
4........	−0.8	−1.0	−0.3	+1.6	+2.3	+0.8	+1.1	0.0	−0.7	+0.9	−0.1	...	+0.2	−0.2	−0.8	0.0	−1.3	−1.9	+0.2	−0.6	+0.8	−1.8	+1.3
5........	−2.7	−1.5	+0.9	−0.3	+6.4	+2.0	+2.8	+0.4	+0.1	+0.7	−0.3	...	−0.4	−0.2	−0.2	−1.9	+0.8	−0.9	+2.3	+0.5	+0.5	−1.0	...
6........	−3.5	−0.4	−0.4	+0.3	+1.5	−1.3	+2.2	...	+0.7	+2.5	+1.0	...	+0.5	+0.1	+0.4	−2.0	−1.8	−1.4	−1.9	−0.9	−0.7	−1.4	+2.5
7........	+0.3	−0.2	−3.9	−2.9	−1.9	−1.2	+1.5	+0.8	−0.7	+1.9	−0.4	+0.5	+1.0	+0.3	−0.5	−0.5	−1.9	−2.0	−0.7	−1.8	−0.3	−1.2	+1.4
8........	−1.4	+0.8	−3.0	+0.5	−7.2	−4.9	0.0	+0.7	−0.2	+1.9	−0.3	−0.1	−1.3	+0.6	−0.7	+0.2	−1.6	−1.9	−0.9	−1.7	−1.8	−1.8	+2.4
9........	−1.9	+0.6	+1.5	0.0	−0.7	−2.0	...	...	...	...	...	...	−1.3	...	−0.6	−0.9	−1.5	−0.6	+1.6	−0.3	−0.1	−0.9	+3.0
1910........	−1.1	+0.6	−0.4	−0.9	−1.9	−2.7	...	...	...	...	...	...	+0.2	...	−0.6	0.0	−2.1	−2.4	−1.4	...	−1.0	−1.1	+3.0
Normals, 1877-1906							16.1	...	15.5	17.2	...	...	14.9	...	17.7	24.2	21.4	16.6	20.3	17.6	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—SEPTEMBER

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton
Normal ...	14°.7C	72° F	77°	81°	79°	72°	86°	76°
Year 1875........	+0.6	−4	−4	...	−3	−5	−3	−4
6........	+1.7	−5	−7	...	−5	−6	0	−8
7........	+0.2	+1	±0	...	−1	+3	−2	+1
8........	+0.2	+1	0	...	0	−1	−1	−2
9........	−0.2	−4	−4	−4	−4	−6	−1	−2
80........	−2.7	0	−1	−4	−2	−4	−7	−2
1........	+1.2	+6	+11	+2	+9	0	+4	−4
2........	+0.8	0	−1	−2	−2	−1	−1	+2
3........	−0.2	−3	−3	−1	0	−7	+3	−5
4........	+0.3	+3	+8	+3	+4	+3	+6	+1
5........	+0.9	0	0	−5	−3	−2	0	−1
6........	−0.6	+2	+2	+2	+1	−1	+3	−2
7........	+0.8	−3	−3	0	0	−4	+4	−2
8........	+1.3	−2	−7	−5	−3	−4	−1	0
9........	−0.7	+1	−3	−2	−3	−1	−3	−3
90........	−1.6	−2	−3	−2	−6	−2	−3	−1
1........	−0.2	+4	+3	+1	+5	+7	0	+4
2........	−0.9	0	0	−2	+1	0	−1	+3
3........	−2.7	−4	−2	+1	+3	+4	+3	+4
4........	−1.1	+4	+2	+1	0	+2	0	...
5........	+0.2	+6	+3	+4	+4	+6	+3	...
6........	+2.5	0	−2	+4	−2	−4	+3	...
7........	−0.8	+1	+3	+3	+10	+7	+4	+10
8........	−1.0	+5	+2	0	+4	+4	0	+2
9........	−0.5	−1	−2	0	+1	−2	+2	0
1900........	+0.8	+5	+5	+4	+4	0	+5	−1
1........	+3.0	+2	−2	−3	+3	−2	−2	−4
2........	+1.1	0	−2	−3	−4	−4	−3	−4
3........	+2.2	+2	+1	−1	0	−3	0	−3
4........	...	−2	0	+3	+1	−1	+3	0
5........	+0.5	0	−2	+2	−1	+2	+2	+1
6........	−0.7	+4	+2	+1	+3	+4	+2	0
7........	−1.6	0	−3	0	−2	−3	+4	−2
8........	−0.9	+5	+4	−1	+3	+8	−1	+7
9........	+0.4	−1	−2	−1	−2	−1	+2	−2
1910........	−0.5	0	−1	+3	−1	−1	+5	−2

Station....	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson
Normal ...	81°	70°	72°	87°	77°	67°	100°	75°
Year 1875........	−1	−1	−1	...	+3	...	...	...
6........	−1	−4	0	...	0	...	...	...
7........	+1	+4	−1	...	0	...	...	...
8........	+1	−2	−3	...	−5	...	−2	...
9........	+1	−1	+2	...	+5	...	+1	...
80........	−2	−2	0	0	−2	+4	−1	...
1........	+1	−6	−3	+2	−6	−3	−2	...
2........	+2	+2	+2	−1	0	+3	−2	...
3........	−5	−1	+1	0	+2	+2	+2	...
4........	+2	−3	+1	+2	−7	−8	−5	...
5........	−2	+1	−2	+2	+1	+2	...	...
6........	−1	−1	...	−2	−1	−1	−1	...
7........	0	0	+1	0	+2	+2	−1	...
8........	+1	+4	+3	−2	+7	+9	+4	+6
9........	−1	−1	−2	−4	−4	±0	−2	+3
90........	−2	+1	0	−1	+1	+3	0	+2
1........	−1	+5	+1	+2	−1	+1	−1	−3
2........	+4	+3	+5	+1	+6	+7	+4	+4
3........	+3	+4	+1	−1	−2	+2	−2	−6
4........	0	+1	−2	−1	−5	−3	−1	−1
5........	+5	+4	+3	0	−1	+4	0	−3
6........	−2	−2	−5	−1	−1	−5	−1	−1
7........	+6	+13	+4	−5	+1	+3	−21	−1
8........	+1	+2	+1	0	+3	+1	+2	+4
9........	+2	+2	+3	+2	+3	+5	+4	+6
1900........	0	−4	−3	+1	−3	−4	—	−5
1........	+1	−5	−1	+2	−2	−9	−2	−1
2........	−3	0	−3	−2	0	+1	0	+4
3........	0	−7	−5	−1	−4	−1	−4	+2
4........	+2	0	0	−5	+1	+6	−5	+1
5........	+3	+6	+2	−1	0	+5	−1	+3
6........	−2	+8	−2	+1	−2	+4	−1	—
7........	+1	−5	−1	0	−2	−1	0	—
8........	+3	+7	+3	−1	−2	+2	−1	—
9........	+2	+6	−2	−3	−2	0	−2	—
1910........	+3	−1	+1	+2	+1	−4	+3	—

Station....	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	76°.6	70°.0	63°.2	81°.8	96°.2	55°.9	75°.1	74°.9
Year 1875........	−0.3	+2.2	...	...	...	...	...	...
6........	−0.1	−0.2	...	...	...	...	...	...
7........	−3.8	−2.7	...	...	...	...	...	...
8........	+1.1	+2.1	...	...	...	...	−4.2	...
9........	−1.9	...	...	...	...	...	−4.8	...
80........	+2.4	−4.3	−0.7	−1.5	...	+0.5	+1.2	...
1........	−0.6	−1.3	+0.9	−0.6	...	+0.1	+0.5	+1.2
2........	+3.6	+0.9	+3.3	+1.2	...	+0.4	+0.4	−1.0
3........	+1.1	−4.3	−3.0	−1.6	...	−2.2	+2.7	+3.7
4........	+1.6	+2.9	—	+2.5	0.0	—	−2.1	−2.2
5........	+6.5	+3.2	+0.3	+2.4	−0.7	−1.4	−4.1	−1.5
6........	+2.2	+3.8	+3.3	+2.9	+1.9	—	+0.5	+1.8
7........	−1.8	+1.1	−1.6	+1.0	−0.1	−0.8	+2.7	+2.4
8........	+5.9	+5.7	+5.0	−1.4	+0.4	+0.7	−3.7	−4.6
9........	+2.2	+0.5	−2.2	+5.0	+3.9	−0.1	+0.3	−0.4
90........	+2.3	+0.3	+1.0	—	−1.3	−0.6	+5.0	+1.2
1........	−2.5	+2.5	+1.0	−0.4	−1.7	−2.0	+1.3	−0.7
2........	−1.4	−1.5	−1.3	−0.6	+3.0	−0.5	+7.6	−5.9
3........	−0.8	−1.6	+0.8	+3.2	+4.2	+0.8	−2.8	−3.7
4........	−2.3	−0.8	−3.6	−5.2	−3.7	−0.1	−0.9	+0.9
5........	+2.5	+2.9	−0.8	+1.2	+0.3	−0.1	−1.1	+3.0
6........	−2.4	+0.1	−0.2	−3.2	−4.0	+2.3	+4.5	+5.2
7........	+0.2	+1.5	+0.1	−1.8	+0.1	+0.5	+1.5	+0.6
8........	+2.8	−0.3	+1.0	−0.2	−1.1	+1.8	−2.1	+5.4
9........	+4.6	+3.9	+0.2	+1.6	−1.0	−0.1	+1.4	—
1900........	−2.4	−3.8	−3.5	−4.8	+0.5	−3.3	—	+2.7
1........	+4.3	+3.4	+0.5	+1.4	−0.6	−0.1	—	−4.7
2........	+0.9	+2.0	+1.4	+2.1	−1.5	+0.2	—	−6.5
3........	...	...	−1.0	−1.4	+0.2	−1.0	+0.1	+4.5
4........	...	...	−1.5	−1.8	−1.1	+0.1	−3.2	...
5........	...	...	−6.7	−6.3	+1.7	−1.1	−4.6	...
6........	...	...	...	...	...	−2.7	0.0	...
7........	...	...	...	...	...	...	...	...
8........	...	...	...	...	...	−1.5	...	−0.6
9........	...	...	...	...	...	...	...	...
1910........	+4.1	...	−0.6	−0.9	+0.3	+1.4	...	...

TEMPERATURE DEPARTURES FROM NORMALS—SEPTEMBER

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	88°.1	91°.1	88°.7	91°.3	97°.0	100°.1	8°.5	20°.0	9°.6	9°.9	19°.4	15°.1	8°.4	23°.6	10°.8	19°.3	15°.8	11°.2	14°.7	13°.4	14°.0	25°.7	32°.3
Year																							
1875........	+1.9	+0.2	−1.0	−0.8	−5.5	+0.5	0.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	−2.4	...
6........	+2.4	−0.3	−0.2	+1.9	−3.1	−3.1	−3.0	−2.9	−3.4	+1.4	...	+2.0	+3.6	...	+3.8	+2.2	+2.7	+1.2	+1.2	−0.6	−1.0	−1.1	...
7........	−0.4	+7.7	+3.4	+0.7	+4.4	+1.0	0.0	+0.8	+1.3	+3.4	+3.8	+2.5	−0.4	...	+1.9	+1.7	−1.7	−3.2	−1.7	−3.1	−2.6	+6.4	...
8........	+1.9	+0.7	+0.9	−1.0	+2.9	−0.3	+0.8	+0.8	+0.2	+1.2	+1.4	+0.9	+1.1	...	−1.9	+0.8	+1.4	+1.0	+2.9	+1.9	1.0	+1.9	...
9........	+2.8	−1.6	−1.3	−1.0	−0.3	−1.8	+2.1	−0.3	0.0	+1.0	−1.5	−1.0	−0.4	...	−1.2	+0.2	−0.7	−0.4	+0.4	+1.6	0.8	+0.7	0.0
80........	+3.9	+0.7	−1.5	−1.6	+3.0	−0.4	+0.5	−1.0	+5.5	−2.0	+1.2	+0.5	+1.6	...	+0.7	−1.4	−0.2	+1.3	−0.2	+0.9	0.1	+0.4	−0.4
1........	−0.7	+1.5	+0.5	+0.9	+1.1	+1.9	+2.3	0.0	...	−0.4	+0.1	−3.8	−2.8	...	−2.4	+0.7	−2.2	−1.7	−2.1	−1.3	−2.0	+0.3	+2.2
2........	−0.5	+1.6	+1.0	−1.5	−4.7	−2.8	+2.4	−0.6	−1.1	+0.1	0.0	+0.3	+0.1	...	+1.3	−1.1	−0.5	+0.7	+0.9	+1.7	0.0	+1.1	−0.9
3........	+0.7	+1.6	−2.2	+0.4	−3.5	+1.3	−2.5	−2.2	−3.4	−0.5	−0.2	+0.2	+0.5	0.0	+1.7	+0.1	+1.0	+2.1	+1.6	+0.3	−0.3	+0.7	−0.9
4........	+3.1	−1.3	−3.6	+1.3	−3.2	−0.9	+1.0	0.0	−1.6	−0.1	−1.3	−3.7	−3.6	−2.6	−3.5	−2.1	−3.8	−2.4	−2.2	+1.3	−0.1	−1.9	−0.7
5........	−2.4	+0.4	+3.5	−0.4	+0.8	−0.2	+0.7	...	...	+0.3	+1.0	+0.5	−0.8	+0.8	−0.8	+0.3	−1.8	−1.6	0.0	−0.2	0.1	−0.7	−2.6
6........	−1.2	−1.1	+5.5	+0.9	+3.7	+3.7	+1.7	...	+1.6	+3.2	−1.0	−1.0	0.0	−1.4	−1.1	−1.9	−2.4	−1.0	−0.1	+1.8	1.6	0.0	−2.8
7........	+1.1	+0.4	−0.6	−2.3	−2.1	+0.6	−0.3	...	−1.5	−0.3	...	+3.8	+4.0	...	+4.5	+2.3	+2.2	+2.5	+2.9	+1.2	0.7	+0.6	−1.0
8........	+1.2	−1.4	+2.3	+0.4	+1.8	+4.2	−1.6	...	−1.6	+2.7	...	+0.9	+1.8	−1.6	+1.2	−0.7	−1.8	+0.3	−0.5	−0.2	−0.7	+0.4	+1.8
9........	−1.2	—	+1.7	−3.0	+2.5	—	−1.1	−1.5	−2.0	+0.4	...	+3.7	+1.6	...	−0.6	+1.8	−1.5	−1.8	−2.9	−2.6	−2.9	0.0	+1.5
90........	−1.0	—	−0.6	−2.7	+0.9	—	+1.1	+0.2	−3.2	−1.4	...	+1.6	+0.7	−1.9	+1.3	+0.9	0.4	+1.2	+0.2	−0.1	−1.0	−0.3	−2.3
1........	+1.8	−1.0	−4.6	+1.6	+1.2	+3.1	+1.1	+0.6	−1.3	+0.7	...	−1.0	−1.3	+1.2	−1.0	+0.2	−0.4	−1.4	+0.9	+0.6	0.3	+0.2	+0.9
2........	+2.4	−0.7	−2.7	−5.6	−3.7	+0.1	+0.2	−1.5	−1.9	+2.2	−1.0	+1.2	+0.8	−0.7	+0.2	+0.9	+1.0	+1.2	+3.3	+3.2	0.9	+0.4	+2.2
3........	−1.0	−3.8	−1.7	−2.6	−4.2	−1.3	−1.6	−0.4	−2.2	+2.4	+2.3	+3.4	+2.0	+2.5	+1.9	+1.1	0.0	−0.4	−1.1	−0.7	0.0	−0.9	+4.2
4........	−3.2	−1.6	−1.3	−1.6	−1.6	+0.3	+2.9	+0.2	−0.7	+1.7	+1.1	+0.5	−0.4	+0.9	−1.8	−1.0	−4.0	−3.4	−2.7	−2.9	−1.8	−0.8	+3.7
5........	−1.3	+0.9	+1.8	−1.2	+3.0	+1.8	−0.2	−0.7	−0.2	+3.8	−0.1	+2.6	+0.3	−1.6	−0.2	−2.0	−2.0	−0.8	−0.9	+1.2	0.9	−1.3	+0.4
6........	−1.2	+4.6	+4.3	−4.1	+2.8	−0.6	+0.4	−1.1	−1.9	+1.5	−0.9	+1.8	+0.9	+0.2	+0.6	+0.9	−0.4	+0.8	+1.6	0.0	−0.2	−0.2	—
7........	−3.0	+1.0	+1.0	−2.5	−1.3	−2.3	+0.2	+0.1	−1.2	+1.0	+1.1	+3.4	+2.6	...	+2.6	+1.8	+1.0	+1.4	+1.4	−0.3	−0.4	+0.3	—
8........	−1.7	−2.0	+0.1	−2.4	−0.5	−1.0	−0.3	−1.4	−2.3	+0.1	−0.9	...	+2.9	0.0	+1.4	−0.6	−1.9	−1.6	−1.0	−0.4	0.0	−1.8	−0.6
9........	−1.0	+2.3	+7.7	−0.9	+7.3	+1.5	+0.8	+0.9	−1.6	+1.5	−0.3	...	+2.4	+1.0	+1.7	+2.4	+0.9	+0.9	+1.0	+0.3	−0.4	+0.8	−0.4
1900........	+0.8	−3.7	−1.3	−1.1	−5.1	−1.6	+2.2	...	+0.6	+2.7	−0.3	...	−0.8	−0.4	−0.8	−1.6	−3.0	−1.3	−0.8	+0.6	0.8	−1.9	−0.4
1........	−0.9	−0.7	−9.4	+2.8	+2.1	−1.0	+1.8	...	+0.1	+1.6	−0.2	...	−1.8	−1.0	−1.8	+0.2	−1.8	−0.6	−1.3	0.0	+0.0	−0.2	−1.6
2........	−1.7	−0.9	+0.1	0.0	−0.4	+0.2	+2.3	...	−0.2	+2.5	−0.2	...	−0.4	−1.0	−1.5	−2.1	−1.9	−2.3	−1.6	−1.2	0.0	−0.7	−0.8
3........	−0.4	−0.9	+0.1	−0.1	0.0	−2.6	+0.6	−0.3	−1.5	+0.2	+0.6	+0.7	−0.5	−0.3	+0.2	−1.4	−1.9	+1.1	+0.8	+0.8	+0.4	−2.2	...
4........	−1.1	+0.8	+0.4	+1.1	+2.1	+0.8	+1.3	−0.4	−2.4	+0.2	−1.4	...	+0.3	0.0	−1.2	−0.1	−1.4	−1.8	−0.1	−1.4	−0.6	−1.3	+1.2
5........	+0.5	−1.7	−1.9	+1.7	+0.6	−1.0	+0.2	+0.4	−1.7	+0.7	+1.0	...	+2.3	+1.3	+1.5	+0.5	+0.7	−0.6	+1.3	+0.2	+1.9	−0.2	...
6........	0.0	+0.1	−2.2	−1.7	−4.6	−3.9	+0.3	...	−1.7	+1.1	−0.1	...	−0.6	−1.1	−1.7	−1.6	−1.9	−2.6	−1.1	−0.7	−0.3	−1.3	+1.3
7........	−2.9	+2.5	+3.1	+1.1	+4.9	+1.8	+1.0	+0.3	−0.5	+2.7	−1.8	−1.0	+0.6	—	−0.7	−1.8	−2.0	−0.9	+0.1	−0.5	+0.6	−1.8	−1.2
8........	−1.5	+2.7	+0.2	−1.9	−4.0	−8.1	−0.1	−1.2	−1.7	+1.2	−0.3	+1.1	+0.7	+1.0	+0.7	+2.1	−0.4	0.0	−0.9	−1.4	−0.9	−1.7	+3.5
9........	+0.4	+0.2	−0.8	−2.2	−4.6	−2.8	...	...	...	...	...	...	+2.8	...	+4.9	+1.6	+3.6	+3.4	+5.4	+2.0	+0.9	−0.4	+2.3
1910........	−0.9	0.0	−1.7	−4.4	+2.5	−0.3	...	...	...	...	...	...	+0.7	...	+0.7	−0.4	−1.8	−0.3	+0.2	...	−1.1	−0.7	−0.8
Normals, 1877-1906							9.1	...	8.4	11.0	...	...	8.8	...	10.8	19.3	14.8	10.7	14.7	13.5	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—OCTOBER

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport
Normal ...	17°.3C	60° F	66°	71°	68°	60°	77°
Year							
1875	0.0	−5	+15	...	−3	−7	−4
6	−0.3	−5	−7	...	−3	−5	−2
7	+2.4	−3	+2	...	+1	−4	−4
8	+0.1	+2	−1	...	−3	−3	0
9	−0.5	+5	+6	0	+6	+7	+2
80	−1.3	0	−3	−3	−2	−3	−4
1	+0.4	+3	+3	+4	+2	−1	+4
2	+3.0	+4	+3	+3	+4	+2	+4
3	+0.1	−2	−2	+3	−5	−7	+4
4	+0.3	0	+4	+6	+4	+1	+3
5	+0.5	0	−22	−6	−3	−5	−5
6	+0.1	+2	+1	+2	+2	+5	0
7	+0.4	−2	−3	−3	−3	−6	−1
8	+0.3	−7	−9	−4	−3	−5	−1
9	+0.1	−2	−7	−1	−4	−4	0
90	+0.3	−3	−5	−3	−3	−3	−2
1	0.0	−2	−3	−2	−1	−1	−2
2	−0.3	−1	−2	+1	+1	+2	+1
3	−2.1	+2	0	0	0	+2	+1
4	−1.3	+1	0	+1	+1	−1	+3
5	−0.4	−4	−7	−1	−5	−5	−3
6	+1.2	−4	−7	−1	−1	−2	−2
7	+1.3	+4	+4	+5	+9	+6	+7
8	−2.0	+1	−2	−3	−4	−5	−2
9	−0.5	+2	+4	+1	+6	+6	+4
1900	+0.1	+7	+8	+3	+7	+7	+3
1	+3.1	+2	+1	+1	+4	+2	+2
2	+0.4	0	0	0	+3	+2	−1
3	−0.7	+1	−1	0	0	0	−1
4	0.0	−3	−1	+2	0	0	+3
5	−0.3	+2	−2	−1	−4	−4	−2
6	+1.4	+1	−4	−10	−2	−2	−6
7	−0.4	−3	−7	0	−3	−1	−1
8	+0.3	+4	+1	+6	−1	0	−2
9	−0.6	−2	−8	0	−2	−4	+3
1910	+0.8	+3	+1	+3	+2	+4	+1

Station....	Yankton	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma
Normal ...	64°	70°	56°	59°	78°	63°	56°	87°
Year								
1875	−3	+4	−1	+5	...	+7	...	...
6	−6	−3	+1	+1	...	+2	...	...
7	−5	−6	−2	−7	...	−3	...	...
8	−2	0	−6	−2	...	−3	...	+2
9	+8	+4	+7	+3	...	0	...	+1
80	−6	−5	+1	−4	0	0	+2	−1
1	−4	−1	−3	−1	+4	−3	−9	−1
2	0	+2	−2	−2	+1	−7	−7	−3
3	−9	−11	−8	−8	−2	−9	−10	−6
4	+2	0	+3	+4	−2	0	+2	0
5	−4	−4	−1	+1	0	+5	+6	...
6	+6	+2	+4	...	−1	−1	−3	−6
7	−5	−2	−3	−2	0	0	−2	+3
8	−2	−1	0	0	+1	+1	+1	+4
9	−1	−3	+5	+1	+1	+1	+5	0
90	−3	0	0	−2	0	−3	−1	+1
1	0	−1	+2	+1	+1	+1	+2	+7
2	+5	−9	+5	−2	−3	−1	+2	0
3	−1	+2	−2	0	0	−1	−6	+1
4	...	+4	0	+3	+2	+1	0	+4
5	...	−4	+2	−1	−4	+3	+3	+3
6	...	−2	−2	+1	−5	+3	+2	+2
7	+2	+3	+4	0	−2	−2	+1	−3
8	−8	−3	−8	−4	+2	−3	−7	+1
9	+3	+4	−2	−3	−1	−5	−7	−2
1900	+6	+4	+6	+3	+1	−1	−1	+8
1	+3	+2	−4	+3	0	+3	+6	+3
2	+3	+4	+2	+2	+3	+3	+3	+3
3	+3	+2	+6	+1	0	0	+5	+4
4	+2	+1	−5	+1	−5	+1	+4	0
5	−5	−4	−4	−6	−2	−4	−6	+2
6	−3	−6	+5	−3	−1	+1	+2	+3
7	+8	0	+4	+3	−4	+5	+6	−1
8	−5	−3	−1	−5	−2	−5	−6	−1
9	−3	0	0	+2	+1	+3	+1	+2
1910	+6	+6	+8	+4	−1	+2	+4	+3

Station....	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	65°	85°.9	78°.1	69°.2	90°.5	101°.9	61°.2	80°.0	80°.6
Year									
1875	...	+1.8	+1.9	...	...	...	...	...	...
6	...	—	−1.0	...	...	...	...	...	...
7	...	−2.8	−7.5	...	...	...	...	...	...
8	...	+3.8	+0.9	...	...	...	...	−3.2	...
9	...	−3.0	−5.5	...	...	...	...	−4.2	...
80	...	−2.4	−6.8	−2.6	− 1.4	...	−0.6	−0.7	...
1	...	−3.8	−5.2	−2.3	− 1.1	...	+3.4	+3.8	+3.4
2	...	−0.3	+3.3	+2.3	− 3.8	...	+0.8	−4.2	−2.8
3	...	−0.1	−1.9	−1.5	− 3.9	...	0.0	+0.7	−1.3
4	...	+2.3	+0.7	−2.0	− 2.3	−1.2	—	−5.0	−5.0
5	...	+9.1	+6.6	+1.8	+ 3.2	−3.1	+0.9	−0.6	−1.5
6	...	−4.5	−1.4	−5.0	− 1.3	−0.8	—	+4.5	−4.0
7	...	0.0	+2.9	+1.4	− 1.5	−1.1	+0.6	+2.4	−2.4
8	+3	+5.8	+3.5	+2.9	− 1.9	+1.8	+2.6	+2.7	+0.7
9	−2	+1.6	+2.9	+1.3	+ 4.5	+3.7	−3.2	+1.3	−5.5
90	−1	+2.4	−1.4	−1.3	+ 4.7	+1.5	−2.8	−6.3	−6.6
1	+3	−1.9	+0.3	−0.9	+ 0.2	+1.0	+0.9	+8.3	−1.0
2	−2	−1.1	−1.9	−2.3	+ 1.6	+0.1	−3.0	+0.7	−3.8
3	−1	+1.8	+3.4	+3.6	+ 5.7	+4.5	−1.8	−2.0	−6.2
4	+1	−3.0	−0.4	−3.9	− 1.5	−2.1	−0.4	+1.4	+2.1
5	+3	+5.2	+7.1	+5.9	+ 0.4	−0.9	+3.6	+5.0	+3.1
6	+4	+7.9	+7.4	+5.3	+ 5.5	−0.1	+3.0	+7.2	+5.8
7	−4	−2.5	−1.2	−2.3	+ 1.4	+1.0	−2.6	+3.4	+0.4
8	0	+2.8	+0.9	+4.0	+ 1.9	−1.6	−1.8	−6.1	−4.4
9	−5	−1.7	−2.6	−1.8	− 4.0	−2.0	−0.3	−2.7	—
1900	−3	+0.5	−1.1	+1.2	− 0.2	+1.9	+0.8	—	−1.8
1	+3	−1.0	−1.7	−1.9	− 5.1	−2.5	+0.2	—	−6.3
2	+1	+1.5	+3.2	+1.3	− 0.9	−0.5	−1.6	—	−0.5
3	+5	...	...	+1.2	− 4.8	−1.3	−2.6	−1.3	−0.4
4	−1	...	...	+0.7	− 6.4	−5.4	−2.2	−2.5	...
5	−1	...	...	−9.1	− 9.6	+0.6	−1.8	+2.0	...
6	—	...	...	...	...	...	−0.7	−3.7	...
7	—	...	...	...	...	...	...	...	...
8	—	...	...	...	...	...	−1.2	...	−0.7
9	—	...	...	...	...	...	...	...	...
1910	—	−4.8	...	−3.9	−10.5	−2.5	−4.4	...	...

TEMPERATURE DEPARTURES FROM NORMALS—OCTOBER

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul
Normal ...	+85°.8	+90°.1	+90°.1	+90°.1	+92°.9	+93°.2	−1°.7	+12°.6	+1°.1	+1°.4
Year										
1875........	+0.5	+0.6	−2.7	+0.1	−5.9	−3.6	+0.2	...	...	...
6........	−3.7	−4.2	+0.5	+5.7	−6.8	−6.7	+3.5	+2.0	+1.0	+2.4
7........	−1.3	+2.5	−1.1	−2.0	−1.9	−3.3	+1.2	−1.1	0.0	+1.8
8........	+0.8	+5.3	+1.1	−1.1	+2.7	+0.3	+0.5	−1.4	−2.4	−0.6
9........	+1.9	−1.6	−2.8	−0.2	+0.5	−0.9	+0.9	−1.6	−1.5	+1.9
80........	−0.7	+1.3	−0.3	+0.1	+4.3	+2.3	−3.4	+0.4	−1.5	+2.8
1........	+1.4	+0.6	+0.4	+2.7	+1.9	+2.2	+0.9	+0.1	...	+1.0
2........	−2.2	−1.1	+1.8	+0.6	−0.1	+1.4	+0.4	+0.7	−2.8	−4.7
3........	−0.1	+1.5	−2.3	−2.2	−1.0	−0.2	+3.9	+0.7	+1.8	+1.9
4........	−0.9	−3.9	−2.6	−0.7	−2.5	−2.2	−1.7	...	−1.3	+1.8
5........	−2.0	+2.5	+1.9	−2.3	+1.9	+1.4	+0.6	...	...	+0.5
6........	−0.6	−1.8	−2.0	−1.2	−2.0	+2.5	−0.5	...	−2.4	−3.4
7........	−1.8	−1.8	−2.6	−2.5	+0.2	+1.7	+0.4	...	+1.3	+2.7
8........	+9.1	+0.9	+1.6	+1.3	−1.5	+0.4	−1.7	...	−2.0	+1.8
9........	+0.3	—	−2.4	−3.8	+0.9	—	−2.9	−0.7	−5.8	−2.7
90........	−2.3	—	−0.5	−1.1	−1.1	—	+2.2	+0.1	+0.6	+3.3
1........	−1.4	−2.0	−2.1	+2.2	−3.5	−0.6	0.0	+2.0	−1.5	0.0
2........	−1.0	+0.3	−2.0	−2.6	+0.7	+0.9	+0.8	−0.6	+0.2	+1.9
3........	−1.4	−2.5	−1.7	−3.3	−0.5	+1.0	+0.6	−1.1	0.0	+1.0
4........	−2.4	−4.7	−1.6	−1.7	+1.5	+2.0	+2.4	+0.8	+1.0	+1.9
5........	−3.0	+0.5	+0.5	−2.8	+0.8	−0.9	−0.3	+0.3	−0.5	+0.3
6........	−1.5	+7.4	+5.6	+6.3	+0.1	−0.8	−0.2	−0.7	−1.1	+2.1
7........	−0.4	−3.2	+0.5	−0.3	−0.2	+1.3	−0.3	+0.9	+0.6	+0.8
8........	−1.5	0.0	+2.1	−0.3	+1.2	+0.8	+1.1	+0.7	+0.7	+1.3
9........	−2.6	+2.4	+7.5	+2.6	+2.9	+0.4	+0.8	−0.8	−0.3	+2.8
1900........	−0.2	−3.1	−0.2	+0.9	−2.0	−1.6	−0.2	...	−1.3	+2.4
1........	−1.5	+3.4	+3.6	+3.1	+4.5	+2.8	−0.4	...	−3.7	−4.2
2........	−4.7	+3.2	+0.9	+1.1	−0.2	−0.6	+0.9	...	−0.7	+0.9
3........	−0.9	−3.5	−1.6	−1.7	+3.2	+0.3	−1.7	−1.3	−3.2	−2.3
4........	−1.7	+0.6	+0.5	+1.5	+2.2	+0.6	−2.9	−1.3	−1.1	+0.5
5........	−2.3	+1.4	+1.4	+1.8	+1.3	+0.5	−0.7	−0.9	−1.0	+0.7
6........	−2.7	+1.0	−0.3	+0.3	+1.2	+0.6	+1.6	...	−1.7	+0.8
7........	−1.8	+5.4	+5.4	+5.4	+4.2	+2.9	0.0	+1.1	−0.3	+0.1
8........	−2.2	+2.9	+1.1	+2.5	−0.2	−3.0	+0.9	+0.7	−1.6	+0.3
9........	−0.7	+1.8	+2.3	+3.0	+0.7	+0.3	...	...	...	...
1910........	−2.9	−1.0	−2.2	−2.1	+2.6	−0.2	...	...	...	...
Normals, 1877-1906							−1.6	...	0.4	2.1

Station....	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	+12°.2	+5°.1	+0°.9	+16°.2	+3°.7	+14°.0	+8°.2	+4°.3	+8°.0	+7°.8	+10°.0	+23°.0	+25°.4
Year													
1875........	...	...	...	...	...	...	...	...	...	...	...	−0.9	...
6........	...	+0.1	−2.0	...	−1.5	−1.4	−1.8	−0.7	−1.7	+0.2	0.8	−1.3	...
7........	+1.0	+0.8	+0.8	...	−0.7	+1.0	−1.6	−0.6	−1.4	−1.5	−1.8	+3.7	...
8........	+0.6	−0.3	+3.4	...	+3.2	+0.7	+2.4	+4.0	+3.7	+2.1	1.2	−0.7	...
9........	+1.2	+1.2	+3.3	...	+2.1	+0.3	+2.4	+1.2	+1.7	−0.6	−1.1	−0.2	+1.3
80........	+3.1	+3.9	−1.3	...	−2.5	+0.7	+1.4	−3.1	+0.3	−1.5	−0.1	+1.4	+1.1
1........	−0.1	+0.4	−0.8	...	−1.7	−1.1	−1.3	−1.6	−1.8	−3.3	−3.3	0.0	−0.1
2........	−2.0	−5.1	−4.7	...	−4.1	−2.9	−3.1	−2.3	−2.1	−1.4	0.6	−1.5	—
3........	−0.6	+2.2	+0.3	−0.8	+1.3	+1.2	+1.7	+1.2	+1.2	+0.4	0.1	+0.5	−2.2
4........	−1.6	+1.1	+2.5	−1.2	+2.0	+0.3	+1.4	+1.5	+0.7	−0.6	−0.7	−0.7	−2.0
5........	+1.2	+1.3	−0.4	+0.8	0.0	+0.7	+1.3	+1.1	+3.4	+0.6	−0.2	−0.2	−3.2
6........	−1.1	−2.5	−3.8	−2.1	−3.1	−1.4	−1.8	−1.1	−1.1	−0.8	1.2	−1.0	−0.3
7........	...	+3.4	−0.6	...	−0.8	+1.0	+1.2	−0.2	0.0	−1.8	−2.7	+3.0	−1.5
8........	...	+6.4	+1.0	+4.4	+0.7	+2.5	+2.5	+0.7	+2.2	−0.3	−1.7	+1.5	+0.5
9........	...	+1.5	0.0	...	+2.7	+0.3	+2.8	+3.0	+3.1	+1.8	1.2	+1.6	+1.9
90........	...	+2.2	+1.6	+0.8	−0.2	−1.0	+0.4	−0.7	−0.2	−1.3	−0.9	−0.3	−2.5
1........	...	+0.5	−4.7	−1.3	−0.9	−0.7	−0.8	−0.2	−0.2	+2.2	1.8	+0.5	+1.4
2........	−0.1	+0.4	+0.4	+0.4	−1.3	+1.4	+0.4	−0.8	+1.4	−0.2	−0.6	+0.4	0.0
3........	−1.1	+1.4	+1.9	−0.5	+2.6	+0.5	+1.8	+2.9	+1.9	+2.7	1.1	−0.8	+3.7
4........	−1.0	+0.1	−1.2	−1.0	−2.2	−0.4	−1.1	−1.1	+0.5	−0.2	0.3	+0.9	+4.0
5........	−1.0	+2.1	+3.9	+0.2	+3.7	+0.1	+3.4	+3.4	+2.8	+0.3	−1.0	−1.6	+5.5
6........	−1.2	+5.0	+4.9	−2.1	+4.7	−1.3	+2.1	+4.5	+4.7	+3.6	1.7	−0.1	−2.8
7........	−0.7	+1.5	−0.7	−0.3	−0.3	+1.3	+0.8	+1.1	+0.1	−0.6	−1.5	−0.8	—
8........	+1.4	...	−3.9	+1.2	−4.6	+0.4	−3.4	−3.4	−1.8	−1.5	0.5	+1.0	+1.7
9........	+2.6	...	+4.4	+1.4	+2.7	+0.2	+0.3	+0.5	+0.1	+0.3	−1.8	−0.8	+0.6
1900........	+1.3	...	+2.3	+1.6	+2.0	+0.5	+3.2	+2.1	+2.5	+1.0	0.1	−0.1	+0.8
1........	−4.0	...	−0.8	+5.0	−0.6	−3.7	0.0	+1.5	−0.1	+1.8	+1.2	+0.2	−5.0
2........	−0.1	0.0	−3.1	−2.2	−2.9	−1.0	−2.0	−1.6	−2.1	−1.3	−1.3	+0.8	−2.7
3........	+1.6	+2.2	−2.1	+1.7	−2.8	−0.7	+0.5	−3.1	+0.5	−0.1	+0.4	−2.2	+0.5
4........	−2.4	...	+1.3	−2.3	+1.3	−0.4	+0.7	+1.5	+1.7	−0.2	−0.5	+0.4	−1.8
5........	+3.5	...	+4.8	+3.2	+4.7	+3.0	+4.2	+1.5	+1.2	−2.7	−4.3	+0.5	...
6........	+0.7	...	−0.5	+1.0	−0.8	+0.2	−0.8	+0.2	−1.9	−0.1	−0.7	−0.9	+1.4
7........	−3.3	−1.0	−0.7	—	+0.9	−1.8	−1.0	1.9	+1.7	+5.2	+3.4	−1.6	−0.2
8........	−3.0	−2.2	−2.7	−3.2	−2.6	−1.7	−2.8	−1.5	−2.1	−1.0	−1.1	−2.1	+1.3
9........	...	...	+2.7	...	+2.9	+0.6	+1.4	+3.3	+4.4	+3.3	+1.0	−0.6	+1.6
1910........	...	...	−2.1	...	−2.5	0.0	−2.1	−1.4	−1.0	...	−0.3	−1.8	+4.8
Normals, 1877-1906	...	...	1.2	...	3.9	14.1	8.8	4.5	8.7	7.7	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—NOVEMBER

Station....	Cordoba	Albany	Pittsburg	Atlanta	St. Louis	La Crosse	Shreveport	Yankton	Dodge	Bismarck	Cheyenne	El Paso	Salt Lake	Helena	Yuma	Carson	Bourke	Deniliquin	Clare	Alice Springs	Daly Waters	York	Bloemfontein	Graaf Reinet
Normal ...	20°.2C	46° F	51°	60°	53°	42°	65°	46°	54°	37°	47°	67°	49°	40°	76°	55°	93°.8	85°.4	76°.9	96°.0	102°.7	69°.0	83°.1	82°.4
Year																								
1875	−0.1	−6	−5	...	−2	−2	+2	−6	+3	−9	−6	...	+1	...	...	...	—	−4.8	...	...	...	...	...	...
6	−2.6	0	−3	...	−4	−3	−2	−8	−2	−3	−1	...	+1	...	...	...	−3.2	−4.5	...	...	...	...	...	...
7	+0.7	0	+1	...	−4	−1	−5	−6	−3	+2	−7	...	0	...	...	...	+3.8	−1.9	...	...	...	...	...	...
8	+1.3	−2	−2	+1	+2	+5	+2	+5	+3	+10	+5	...	+5	...	−1	...	+0.7	−1.7	...	...	...	...	−2.8	...
9	+0.9	0	+1	+1	+4	−1	+5	−1	+2	+3	+1	...	−5	...	−2	...	−2.3	−6.8	...	...	...	...	−1.2	...
80	+0.5	−1	−7	−5	−13	−9	−12	−12	−19	−4	−16	−4	−11	−13	−5	...	+0.6	−5.6	−1.9	+1.7	...	−1.0	−2.8	...
1	+0.5	+3	+2	+1	0	+2	−1	−4	−3	−1	−7	−5	−8	−5	−5	...	−9.3	−3.2	−1.6	+0.8	...	+0.7	−2.4	−1.0
2	+0.3	+1	−3	−1	−1	+1	−2	0	+2	−1	−1	−3	−4	−2	−4	...	−0.1	+3.8	+2.5	—	...	−0.4	−1.1	+0.8
3	+0.1	+5	+4	+2	+6	+3	+2	+3	+2	+2	+4	−2	−2	+2	−1	...	+0.1	−0.3	−1.1	−2.0	...	−2.6	+1.5	+3.2
4	−0.3	+1	+2	+1	+3	0	0	0	0	+5	+2	+1	+3	+5	+2	...	−0.3	+1.8	−2.8	−1.1	−3.5	—	−3.1	−2.1
5	+1.9	+1	−1	−1	+3	+2	+2	0	+4	+2	+4	+1	+4	+8	−2	...	+4.3	+2.1	−1.8	−0.6	−2.1	−0.3	+3.3	−0.9
6	0.0	+3	−1	0	+2	−1	+1	−5	0	+1	...	−5	−9	−1	−6	...	−2.3	+5.1	+1.5	−1.1	+0.8	—	+3.0	−3.5
7	−0.5	0	+1	+2	+3	0	+4	+3	+3	+5	+4	+2	+5	+4	+3	...	−1.5	−0.2	−2.7	−2.0	−2.2	+1.4	+0.8	−4.9
8	+0.5	+2	+1	0	−1	+3	−2	+2	−3	+4	−3	−3	0	−7	−2	−4	+9.0	+8.2	+6.2	+4.0	+3.4	+3.2	+2.0	+0.1
9	−1.1	+4	−1	−1	−5	−2	−4	−3	−6	+1	−7	−4	−1	0	0	−3	+0.5	+2.9	−0.2	+5.2	+0.8	−2.4	−3.3	−0.3
90	+2.8	−1	+1	+8	+4	+4	+3	+5	+5	+1	+3	+5	+2	+6	+2	+2	−2.4	−3.4	−5.7	−1.5	+2.0	−0.2	−4.5	−4.2
1	−0.6	0	−1	−2	−6	−3	0	−5	−1	−4	+1	+1	+3	+2	+5	+6	+4.8	+2.0	−0.6	−3.2	−0.9	+1.6	+4.4	+1.2
2	−0.4	−2	−3	−1	−5	−4	0	0	+1	−2	0	−3	+2	+4	+2	+3	−2.6	−0.6	+1.4	+3.4	+0.6	−2.6	+2.8	+2.2
3	−1.2	0	−1	−1	−1	+1	−1	−1	−1	−1	−1	−2	−1	−1	−1	−1	−1.8	−2.4	−1.6	−1.5	+2.3	−2.0	+0.4	+0.3
4	+0.7	−3	−3	−2	−2	−6	+2	...	+5	+1	+6	+5	+7	+9	+8	+7	+2.7	+2.5	+1.1	+1.2	−1.0	+2.5	+3.4	+3.8
5	−1.0	+2	+3	+1	−3	−1	−1	...	−1	−5	−4	−4	−3	±0	−2	−1	−0.1	+2.1	−0.1	−3.4	−2.4	+4.1	−0.6	+7.9
6	+0.5	+5	+5	+4	+1	−6	+3	...	−3	−22	−5	+2	−3	−13	0	−3	−3.6	+5.8	+3.2	−0.2	−2.1	+3.0	+3.0	+0.6
7	−0.2	0	+2	+3	+2	−1	+3	−2	+4	−2	+3	+4	+4	−3	+1	+1	+4.9	+5.4	+3.2	+1.0	+4.0	−0.8	+0.5	+0.6
8	−1.9	0	−1	−3	−2	−2	−3	−3	−3	−2	−6	−1	−3	−4	−1	−2	+1.5	−4.3	−4.7	−2.1	−1.4	−2.0	+0.3	+2.5
9	+0.4	0	+3	+3	+7	+8	+5	+9	+6	+12	+6	+2	+7	+8	+2	0	−0.9	−3.7	−2.0	+0.2	+2.9	−2.8	−2.3	—
1900	+1.5	+2	+2	+1	+3	−5	+2	−3	+3	−8	+3	+1	+4	−2	+4	0	+6.1	+0.8	+3.2	+0.9	—	+0.3	—	+0.8
1	+1.4	−5	−6	−4	0	−1	+1	−1	+7	+3	+7	+1	+6	+8	+5	+2	+5.9	+5.8	+4.7	+1.7	−0.1	−0.4	—	−4.1
2	+0.6	+6	+8	+5	+7	+6	+4	+2	+1	+2	+1	+1	0	−1	−4	−5	+4.2	+5.1	+4.9	−3.4	−0.7	−1.7	—	−1.6
3	−1.3	−2	−4	−5	−3	−2	0	−4	+1	0	+2	+5	+3	−4	+4	+2	...	...	+0.1	−5.6	−1.3	+0.9	−2.0	−0.6
4	−1.9	−4	+2	0	+4	+6	+3	+10	+7	+13	+8	−2	+7	+10	+4	+3	...	...	−0.4	−2.8	−0.6	−0.7	+1.4	...
5	−1.0	0	−3	+2	+2	+3	+3	+5	+5	+7	+1	−4	+2	+1	−5	—	...	...	−1.8	−1.2	+1.7	−1.8	0.0	...
6	+0.7	−1	0	+2	−2	−1	+2	−4	−4	0	−5	−4	−2	−2	−1	—	...	...	...	...	...	−1.4	−4.2	...
7	−0.6	0	−3	−2	−1	0	−2	+3	+2	+8	0	−7	+1	+7	+1	—	...	...	...	...	...	...	...	...
8	−0.3	+1	+1	+5	+4	+4	+4	+3	+3	+6	−3	−3	0	+3	+2	—	...	...	...	...	...	−2.2	...	−0.2
9	+2.2	+4	+8	+7	+10	+7	+9	+2	+6	+4	+1	+3	+3	+5	0	—	...	...	...	...	...	...	...	...
1910	+0.4	−3	−9	−2	−3	−6	+3	−2	+6	−2	+3	+2	+7	+1	+1	—	−7.9	...	−1.9	−6.6	−2.3	−2.8	...	...

TEMPERATURE DEPARTURES FROM NORMALS—NOVEMBER

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent
Normal ...	+77°.9	+83°.0	+85°.2	+87°.2	+82°.0	+82°.1	−15°.7	+3°.8	−10°.5	−8°.9	+6°.4
Year											
1875........	0.0	+0.8	−1.5	+1.5	−1.5	−1.3	−2.1	−2.1	...	...	...
6........	+0.1	−0.4	−0.4	+3.5	−2.6	−3.8	+0.7	+0.1	+0.4	−2.6	...
7........	+1.3	+6.0	+2.3	+1.0	−0.1	−4.6	+0.7	−1.7	+1.4	+0.6	−1.7
8........	+3.5	+1.9	+2.0	+0.9	+1.8	+0.4	−5.0	−1.8	−3.5	+3.8	+0.8
9........	+3.8	−2.5	−3.3	−0.5	−2.1	−3.3	+3.3	+1.3	+0.1	−1.1	+0.9
80........	+1.2	−1.1	−2.0	−2.8	−0.6	0.0	+0.7	−0.7	+3.6	+8.1	+1.9
1........	+0.9	+0.8	−1.5	+0.7	+0.5	+0.6	+0.7	+0.4	...	−1.0	−1.1
2........	−0.3	−2.4	−3.2	+0.2	−0.4	+0.5	+0.6	−0.7	−2.8	−1.5	+2.6
3........	+0.1	−1.2	−2.2	−2.0	−4.3	−2.3	+0.6	−2.2	−2.9	−6.0	−1.7
4........	−2.1	−3.8	−1.9	−0.4	−2.1	−1.8	+1.5	...	−0.1	−1.6	−2.2
5........	−0.5	+1.3	0.0	−2.1	+2.6	+2.8	−2.7	...	...	+0.3	+1.2
6........	−0.5	0.0	+0.6	−0.1	+0.6	+0.9	−1.1	...	−0.3	−1.7	−1.1
7........	+0.5	−1.1	−1.5	−1.9	+0.1	+0.7	+0.9	...	+3.9	+5.4	...
8........	−0.4	−0.2	−0.4	−1.1	−0.5	−1.0	+2.1	...	+0.5	+1.7	...
9........	+2.0	—	−0.9	−1.2	+0.3	—	−1.2	−1.6	−1.3	−6.2	...
90........	−0.8	—	−1.3	−2.4	−3.4	—	+2.3	+0.6	+0.3	−5.5	...
1........	+0.6	+0.2	−0.7	+1.8	+1.1	+2.8	−4.6	−1.3	−1.1	−0.5	...
2........	−0.2	+0.1	−1.7	−2.7	+0.2	+0.6	−1.7	−1.3	−5.1	−8.8	−1.1
3........	−0.9	−4.1	−2.1	−2.3	−1.2	−0.5	+1.9	−0.8	+2.7	+6.0	+2.6
4........	−0.7	−3.6	−4.2	?	−1.8	−0.2	+2.5	+0.3	−0.1	+1.8	−2.0
5........	+1.1	+2.6	+3.9	−0.1	+2.2	+1.1	+0.4	+0.3	+3.1	+3.8	−0.6
6........	−0.3	+2.4	+3.6	+3.3	−1.0	−0.2	+2.8	+2.2	+3.4	+3.9	−1.9
7........	−0.6	−0.3	+1.6	+2.5	−0.3	+1.9	+3.4	+1.0	+0.3	+1.6	+2.2
8........	−0.4	+1.0	+2.9	−0.7	−0.4	+0.1	+4.5	+1.6	+3.5	+4.6	−2.6
9........	−1.1	+1.9	+6.9	+3.3	+2.9	+1.3	+4.8	+0.3	+3.9	+4.9	−0.9
1900........	+1.1	+1.8	+2.0	+2.7	+3.4	+2.3	−0.5	...	−2.5	−1.0	+0.9
1........	−0.8	+2.2	+1.8	+0.3	+3.5	+2.4	+1.7	...	+2.7	+4.9	+2.4
2........	−1.1	+0.8	+0.2	−0.9	+1.4	+0.5	+1.2	...	+0.1	−0.9	+0.1
3........	−0.4	−1.3	−0.6	−2.8	+1.7	−0.3	+1.5	−0.8	−0.7	0.0	−0.4
4........	−2.3	−2.8	+1.3	+1.3	−0.7	0.0	+3.9	...	+3.0	+4.2	+3.2
5........	−0.8	+2.2	+2.1	+3.6	+2.5	+1.6	−0.5	−0.4	0.0	+3.0	+2.0
6........	−0.3	+1.9	+1.3	+2.9	+4.4	+3.7	−2.0	...	−5.4	−0.9	+1.4
7........	−0.1	+3.5	+3.9	+3.0	+4.9	+3.2	−4.8	−2.1	−2.0	−3.2	−1.0
8........	−1.3	+1.8	+0.7	+2.5	+0.5	−1.8	−1.6	+0.3	−0.7	+0.2	+3.1
9........	+1.3	+3.1	+3.0	+4.3	+4.0	+2.5	...	...	...	...	...
1910........	−0.7	−2.4	−2.8	−2.6	+1.7	−0.8	...	...	...	...	...
Normals, 1877-1906							−14.9	...	−10.2	−8.1	...

Station....	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	−2°.4	−7°.0	+7°.4	−3°.6	+7°.6	+1°.4	−2°.5	+2°.2	−1°.5	+3°.3	+18°.5	+19°.2
Year												
1875........	...	...	...	...	...	...	...	...	...	...	−1.1	...
6........	−5.4	−0.7	...	−2.8	+1.5	−2.0	−2.5	−4.0	−0.6	−3.2	+1.8	...
7........	−2.1	+4.4	...	+2.4	+0.3	+1.2	+4.3	+1.1	+5.7	1.3	−0.3	...
8........	+2.8	+4.9	...	+5.1	+1.2	+5.3	+4.5	+5.3	+5.2	0.6	+1.8	...
9........	−2.7	−1.0	...	−2.3	+1.1	+1.4	−1.3	−0.8	+1.7	−2.5	−0.8	+2.0
80........	+1.6	+3.2	...	+1.4	+1.7	+0.4	+2.2	+1.0	+4.3	1.7	+1.0	−0.2
1........	−3.6	−2.2	...	−2.4	−1.8	−1.2	+0.1	−1.5	+4.6	−0.5	−0.9	−0.7
2........	+0.8	+2.2	...	+1.7	+0.5	+4.0	−1.0	+0.7	+3.4	1.5	−0.8	+1.0
3........	−2.1	+0.9	−0.9	+1.9	−0.1	+1.2	+3.5	+1.1	+4.9	0.4	+0.4	−1.3
4........	−1.5	+1.0	−1.9	+0.9	+0.4	−0.4	+0.1	−1.4	+1.3	−1.3	−0.9	−1.0
5........	−1.6	−2.3	+3.1	−4.1	−0.1	−1.6	−3.1	−1.8	+2.0	0.6	+0.3	−0.4
6........	−1.2	−0.5	+2.4	−0.1	−1.3	+1.5	+3.3	+2.4	+5.6	1.7	−1.6	−1.0
7........	+3.2	+2.0	...	−0.4	+1.6	+2.2	+1.2	+1.8	+4.6	0.9	+1.2	+1.9
8........	−0.1	−2.6	+1.5	−2.5	−1.0	−2.3	−0.2	−2.5	+2.3	−1.6	−1.2	+1.7
9........	−5.5	−4.4	−0.7	−3.4	−1.4	+0.6	+2.8	+2.3	+4.7	−0.3	−0.9	+0.8
90........	−5.8	−9.7	+1.7	−6.5	+0.8	−1.2	−3.9	−0.2	+4.6	0.4	+0.8	−1.0
1........	−5.0	−6.5	+1.1	−7.2	−1.3	−3.3	−4.5	−3.4	+2.6	−0.8	+0.7	+1.1
2........	−1.6	−0.6	−1.2	−1.1	+0.7	−0.7	−0.3	−2.2	+2.4	−1.9	−0.6	−0.3
3........	+0.2	+2.3	+2.7	+1.2	+1.8	+2.9	+1.1	+1.0	+2.8	−0.8	+1.0	+1.4
4........	−1.9	−3.5	−1.1	+1.0	−1.1	−1.3	+1.7	−1.7	+4.8	0.9	−0.4	+0.9
5........	−1.2	−1.4	+0.3	−1.3	−1.0	−1.3	+0.8	+0.1	+4.0	1.8	−0.8	+5.4
6........	+0.3	−2.8	−1.2	−2.6	−2.0	−2.5	−1.7	−2.4	+1.2	−0.4	+0.4	−3.1
7........	−1.4	−1.4	+0.9	−1.4	−3.0	−2.7	−0.5	−3.5	+2.5	−1.4	−3.7	—
8........	...	0.0	−1.8	+1.4	−1.2	+1.8	+3.8	+1.7	+6.3	2.7	+0.2	+0.5
9........	...	+4.4	+0.1	+3.2	−0.5	+2.1	+2.8	+1.1	+5.7	3.0	−1.5	0.0
1900........	...	−0.8	0.0	−1.5	−3.2	−1.8	−0.6	−1.9	+6.7	3.1	−0.2	−3.1
1........	...	+0.3	+1.8	−0.9	−0.2	−0.2	−0.4	−1.0	+4.3	0.0	+0.4	−1.8
2........	−3.3	−6.5	0.0	−5.8	−2.2	−4.8	−2.6	−5.7	+0.2	−2.6	−0.2	−1.1
3........	−2.0	+0.8	−0.4	+0.9	+0.1	+1.3	+2.6	+1.0	+4.5	+2.4	−2.1	−2.2
4........	...	+2.1	+4.4	+0.9	+0.4	+1.0	+0.5	−0.6	+2.9	+0.2	−1.4	−1.6
5........	...	+3.3	+2.8	+1.5	+2.1	+3.9	+2.3	+2.5	+5.2	+1.4	+0.5	...
6........	...	−0.9	+0.7	−1.9	+0.3	+1.0	+1.8	−3.8	2.5	+3.9	−0.5	−0.3
7........	−7.5	−6.5	−2.1	−7.0	−2.9	...	−3.7	−5.7	0.5	−0.5	−2.0	+0.6
8........	−2.3	−2.5	+2.7	−4.2	−2.0	−3.5	−4.4	−5.8	+0.4	−2.7	−2.4	+1.7
9........	...	+4.6	...	+1.4	+1.8	+4.0	0.0	+0.4	+2.8	+0.1	+0.1	+0.5
1910........	...	−0.1	...	−6.1	+0.7	+2.6	+1.0	+1.7	...	+0.4	−1.8	+2.8
Normals, 1877-1906	...	−7.5	...	−4.3	7.3	1.6	−1.9	2.0	2.5	...	...	...

TEMPERATURE DEPARTURES FROM NORMALS—DECEMBER

TEMPERATURE DEPARTURES FROM NORMALS—DECEMBER

Station....	Sibsagar	Benares	Nagpur	Bellary	Lahore	Dera Ismail Kahn	Nerchinskii	Pekin	Irkutsk	Barnaul	Tashkent	Irgiz	Ekaterinburg	Kizil Arvat	Kazan	Tiflis	Lugansk	Moscow	Elisabethgrad	Warsaw	Vienna	Abbassia	Laghouat
Normal ...	+71°.3	+75°.1	+81°.8	+86°.0	+71°.3	+72°.3	−26°.3	−2°.4	−16°.8	−15°.5	+2°.7	−11°.2	−15°.0	+2°.9	−12°.0	+2°.5	−5°.3	−8°.1	−3°.5	−2°.9	+0°.5	+14°.5	+15°.2
Year																							
1875........	−0.4	+1.7	+1.0	+1.4	−0.5	−2.0	+2.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	−0.5	...
6........	+2.0	+0.4	+0.1	+1.2	+1.4	+1.0	−3.0	−0.4	−3.8	−1.7	...	−3.0	−6.2	...	+6.0	+4.4	−2.4	−9.6	−2.8	−2.2	2.5	+1.0	...
7........	+0.4	+1.5	+1.3	+2.6	−6.1	−7.9	−0.1	−2.6	−5.1	−11.7	−9.3	−6.8	−1.2	...	−1.1	−2.0	−0.4	−3.4	+0.5	+0.5	0.4	+0.3	...
8........	+4.6	+1.8	−0.1	+1.9	+1.2	+0.5	−3.7	−2.4	−5.6	−3.3	+2.3	+2.7	+6.3	...	+6.2	+3.6	+7.0	+4.2	+4.2	+1.4	−1.4	+2.2	...
9........	+3.1	−1.1	−3.1	+0.2	−0.5	−1.7	+2.4	+1.0	+1.0	+4.1	2.2	+1.5	−1.5	...	−2.1	+1.9	−0.7	−2.0	−4.7	−5.4	−6.9	+0.1	−3.1
80........	−0.8	−0.2	+0.2	+0.1	−2.1	−2.0	+1.6	−1.4	−0.9	+3.1	2.0	+3.5	+5.1	...	+3.7	−1.3	+3.7	+2.1	+1.7	+2.7	4.3	−1.7	+0.1
1........	+2.1	+2.6	+1.0	+1.1	+3.1	+3.7	+23.2	...	...	−3.0	−8.4	−5.1	+0.8	...	−1.0	−2.2	−0.6	+0.8	−1.2	+1.6	1.2	−0.7	−3.1
2........	+1.1	+2.4	+1.1	−0.8	+2.9	+3.7	−1.8	−2.6	−11.2	−7.1	+2.0	−3.0	−2.8	...	−1.0	+2.4	−0.9	−3.9	−2.0	+0.8	2.1	0.0	—
3........	−1.9	−1.0	−4.0	−2.5	−0.9	−0.1	+4.2	+0.8	+4.8	+1.2	+1.7	−2.0	+4.2	2.0	+3.6	+1.2	+3.0	+3.7	0.0	+2.2	1.5	−0.5	−1.4
4........	−1.6	−1.3	−4.9	−0.4	+0.5	+1.5	+1.1	...	−1.1	+3.3	0.5	+4.4	+6.9	...	+6.2	+1.0	+6.7	+4.7	+5.3	+4.3	2.2	−0.2	−1.0
5........	−0.9	−3.6	−5.1	−2.1	−0.6	+0.6	+3.5	...	...	+4.8	−1.1	+3.0	+4.3	−0.8	+3.4	+1.0	+3.6	+2.0	+1.0	+0.9	−0.4	+0.6	+1.7
6........	+0.1	0.0	−0.8	−2.0	+1.2	+1.1	+2.4	...	+5.4	+4.6	−2.6	+0.4	+8.9	−0.6	+8.7	+1.3	+9.7	+6.6	+7.3	+3.0	1.9	−0.1	+2.2
7........	+0.4	+0.9	−2.2	−2.8	+2.0	+0.2	+0.1	...	+1.3	+4.3	...	+5.6	+5.3	...	+5.5	+2.9	+8.2	+3.3	+3.6	+0.7	−0.6	+0.4	+0.9
8........	−0.2	−0.8	−0.7	−1.2	+1.1	+1.2	+1.9	...	+0.3	−0.7	...	−3.4	−5.2	+1.2	−4.6	−0.9	−3.4	−4.8	−3.6	+1.4	0.8	+0.1	+1.3
9........	+2.0	—	+1.3	−0.5	+4.1	—	−0.1	0.0	−1.0	−3.8	...	−4.0	+2.7	−2.4	+0.5	−0.5	−2.7	0.0	−4.0	−0.6	−3.3	−0.2	−2.1
90........	−2.4	—	−0.3	+0.1	−6.0	—	+0.2	+0.6	−1.1	−0.6	...	−6.6	+2.6	−2.6	−0.1	−1.3	−4.3	−4.8	−6.9	−4.2	−4.8	+1.4	−2.3
1........	+2.3	−0.3	−1.1	+1.6	+1.6	+3.0	−1.6	+0.1	+0.8	+1.8	...	+0.4	+2.2	+1.5	+6.2	+1.1	+5.1	+4.4	+1.2	+3.1	1.8	+0.2	+1.4
2........	−0.4	−1.0	−0.7	−1.6	−0.5	−2.5	−1.2	−0.6	−0.2	−0.3	+2.4	−1.6	−3.1	+1.8	−4.5	+1.4	+0.6	−4.2	−2.2	−0.5	−1.2	−0.7	+0.5
3........	−2.1	−1.4	−1.4	−2.0	+0.9	+0.4	−2.4	+0.3	−0.8	+2.5	+2.0	+4.3	+2.6	+1.8	+4.	+0.6	−1.2	+2.5	+0.9	+3.1	1.1	−0.6	−0.9
4........	−2.1	−0.6	+0.1	?	−3.8	−2.0	+4.3	−0.2	−1.5	−2.8	−2.6	−6.9	−1.3	−2.7	−0.4	−0.5	+0.2	+1.4	0.0	+1.9	0.4	0.0	+0.7
5........	+1.3	−0.1	+0.2	−2.6	+0.6	+1.6	+3.0	+0.2	+0.3	+0.3	+1.1	−1.0	−0.8	+3.3	+1.0	+2.4	−2.0	−3.2	−3.3	−0.5	0.1	−0.1	+3.2
6........	+0.5	+0.5	+2.7	+1.6	−2.2	+0.9	+1.6	−0.3	−0.7	−2.6	−1.1	−2.3	−2.0	+0.4	−2.7	+0.3	+1.7	−2.3	+1.9	+0.4	0.6	+0.5	−0.4
7........	+0.7	−0.8	+0.2	−0.1	−3.0	+0.5	+3.0	−2.2	−4.5	−2.1	−0.1	−2.9	−1.5	−1.0	−3.9	−1.5	−1.6	−2.3	−2.7	+1.2	0.2	−2.3	—
8........	+0.5	+1.3	+3.5	+1.0	−1.6	−0.9	+4.7	+1.9	−4.1	+8.2	+0.9	...	+6.5	+1.2	+5.5	+0.7	+6.0	+4.6	+4.3	+5.0	3.0	−1.1	−0.5
9........	−3.8	+2.3	+5.7	+2.2	+5.9	+2.8	+2.4	−0.9	−4.4	−5.0	−3.4	...	−1.7	−5.2	−2.5	−2.5	−3.3	−3.0	−4.0	−1.1	−4.0	−1.1	+0.8
1900........	+0.9	+0.3	+4.1	+3.7	−2.9	−3.5	+0.8	...	−2.0	+2.3	+1.3	...	+2.7	+2.4	+3.0	2.5	+4.3	+2.0	+3.7	+3.8	2.0	+0.3	−0.2
1........	−0.2	+1.1	+1.3	+0.1	+3.9	+1.8	−5.5	...	−8.4	0.0	+2.2	...	−2.1	+4.5	−1.0	+2.8	+6.1	−0.5	+5.7	+3.9	+2.6	+0.3	−2.5
2........	−0.5	−0.1	−2.8	+0.5	+1.4	+0.3	+2.4	...	−0.1	−1.6	+1.7	+0.1	−4.1	+3.0	−1.8	+0.4	−0.1	−3.6	−4.4	−2.8	−3.4	−1.2	+0.5
3........	+0.2	−0.5	+1.4	−1.0	+1.2	−0.3	−0.1	−0.6	−3.6	+0.2	−2.0	−1.6	+2.9	−1.9	+0.6	+0.3	−0.8	+0.6	−0.4	+1.1	−0.2	−0.9	−2.6
4........	−2.6	−1.4	+1.4	+0.2	+1.2	+1.0	+3.2	+0.4	+1.0	+7.3	+2.1	...	+0.9	+3.0	+1.5	−0.6	+3.7	+0.6	+3.2	+3.2	+1.2	−2.0	+0.3
5........	−1.4	+0.4	+1.0	+2.2	−1.7	−2.9	+0.4	+0.9	−0.9	+3.3	−0.4	...	+5.9	+1.0	+4.9	+0.3	+2.6	+3.3	+1.6	+2.4	+1.2	−2.0	...
6........	+1.1	+1.4	+0.5	+1.1	+3.5	+2.5	+4.4	...	+2.3	+3.1	+2.6	...	+3.3	+2.9	+1.8	+2.7	+4.1	+1.0	+1.9	−1.2	−1.7	0.0	−1.6
7........	+0.5	+0.9	−0.4	+0.6	+2.9	+1.0	−3.8	−1.3	−1.2	+3.9	+0.9	−1.4	−2.9	+1.6	−1.2	−0.3	...	−5.5	−0.7	−0.2	+1.7	−1.5	+2.1
8........	+0.2	+1.0	−1.7	−0.4	+0.3	−2.4	+0.2	+1.8	+0.4	+3.2	−0.1	−0.8	−0.9	+1.3	+0.0	−1.4	−3.6	−1.1	−2.3	−0.3	−1.9	−3.0	−0.2
9........	+0.7	+0.2	−2.4	+2.4	−2.7	−3.8	...	...	...	...	...	...	+5.7	...	+2.9	+1.8	+4.6	+4.5	+2.9	+3.7	+1.2	0.0	+2.4
1910........	0.0	+0.7	+0.9	−1.1	−0.2	−3.1	...	...	...	...	...	...	+3.9	...	+5.0	−1.9	+2.7	+5.5	+1.6	...	+3.1	−1.7	−0.5
Normals, 1877-1906							−25.3	...	−17.8	−15.1	...	...	−13.4	...	−10.7	3.1	−3.5	−7.8	−3.2	−1.8	...	...	...

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EXPLANATION OF TABLES

TABLE 1W.—Deviations of the surface temperatures from the eleven-year means (1900 to 1910) for each decade and each 2° longitude field of the northerly shipping route Channel to New York. The first column for each year gives the number of observations, the second column the temperature deviations in tenths of a degree Centigrade. M_1 and M_2 give the mean values for the two decade groups of three each as follows: I-III, February 3 to March 4, and V-VII, March 15 to April 13. The numbers within brackets indicate interpolated values. Italicized numbers indicate mean values in the computation of which obviously false observations have been omitted.

Feld	Dekade	Mittel 1900-10	1898		1899		1900		1901		1902		1903		1904		1905		1906		1907		1908		1909		1910	
49° N.	I	10.01	13	3	8	4	7	1	7	−5	12	−9	6	3	9	−11	14	5	17	5	18	−1	22	1	18	9	18	4
10°–11°	II	10.15	8	6	10	3	11	5	11	−11	5	−4	14	6	13	−2	20	3	29	−2	2	−2	14	7	16	5	23	−4
W.	III	10.10	4	9	7	1	10	−0	10	6	7	−1	20	1	8	−0	16	−3	15	3	25	−3	19	−1	22	−0	21	−1
	M_1	10.07	25	5	25	3	28	3	28	−3	24	−6	40	4	30	−4	50	2	61	2	45	−2	55	2	56	4	62	−1
	V	10.03	5	5	7	7	5	1	3	−10	6	−0	6	7	11	−3	20	3	24	1	16	2	16	−2	21	4	10	−2
	VI	10.18	4	[1]	11	8	10	−5	4	[−8]	11	−1	14	4	20	−7	21	3	24	−3	24	6	18	6	25	4	20	0
	VII	10.33	10	12	11	4	7	2	7	−3	12	−6	5	−0	8	−4	22	7	19	3	14	1	18	−1	22	5	16	−3
	M_2	10.21	19	6	29	6	22	−1	14	−4	29	−3	25	4	59	−6	63	4	67	−0	54	3	52	1	68	4	46	−2
[illegible]	I	10.52	10	1	5	3	9	−1	9	−6	12	−8	3	1	8	−8	13	6	16	4	21	0	20	4	16	6	19	3
[illegible]°	II	10.64	10	2	5	4	12	−2	7	1	5	−6	13	5	13	−7	28	3	31	−5	24	3	13	4	17	9	28	−4
	III	10.66	6	5	5	1	13	−1	13	2	8	5	20	−3	9	−3	15	−3	13	2	24	−0	18	−1	21	4	20	1
	M_1	10.58	26	2	15	3	34	−1	29	−1	25	−4	36	1	30	−6	56	2	60	−1	69	1	52	2	54	6	67	−0
	V	10.38	5	6	5	0	7	−2	4	−7	7	−2	5	−3	6	−0	22	−1	22	−2	18	5	19	1	25	5	10	6
	VI	10.70	6	−2	11	2	5	−1	2	−7	7	1	13	6	11	−8	19	−1	23	−2	26	2	19	1	19	6	27	2
	VII	10.82	8	6	12	−1	6	0	9	−2	9	−1	4	1	9	−6	22	3	20	1	14	3	20	−2	23	6	15	−4
	M_2	10.66	19	4	28	1	18	−1	15	−4	23	−1	22	3	26	−5	63	0	65	−1	58	3	58	−0	67	5	52	1
[illegible]	I	10.66	14	4	8	−1	11	−7	8	−4	12	−2	6	1	8	−12	11	11	16	5	20	1	15	−0	11	1	19	6
	II	10.72	9	12	7	4	11	−4	12	−4	7	−1	9	4	14	−8	20	3	30	−4	27	4	16	4	17	6	27	1
	III	10.72	6	7	7	2	12	2	7	0	8	1	20	−0	11	−6	16	2	15	1	23	0	14	−1	23	1	24	−2
	[illegible]	10.68	29	7	22	2	34	−3	27	−3	27	−1	35	1	33	−8	47	5	61	−0	70	2	45	1	51	3	70	2
	[illegible]	10.59	4	4	8	−3	10	−4	4	−3	8	−0	5	−5	13	−1	19	−3	23	0	19	6	13	3	20	6	12	2
	[illegible]	10.77	6	2	10	8	9	−0	4	−8	9	−3	9	−4	13	−5	22	3	26	−1	22	5	22	2	21	8	22	3
	[illegible]	11.05	9	10	12	−1	7	−5	8	−3	13	−0	5	1	11	−12	21	4	16	3	12	3	17	2	22	7	16	−1
	[illegible]	10.81	19	7	30	2	26	−4	16	−4	30	−1	19	−3	37	−6	62	2	65	0	53	4	52	2	63	7	50	1

	[illegible]	10.89	9	6	8	−3	6	1	13	−5	8	−2	7	−1	9	−16	8	4	14	4	14	3	17	5	20	5	17	3
	[illegible]	10.9[illegible]	5	5	6	1	10	4	9	−1	4	−4	10	5	12	−8	15	1	22	−6	19	5	14	2	12	5	17	−3
	[illegible]	10.84	5	7	4	3	11	−4	6	2	9	−1	20	−1	8	−7	11	−2	14	−1	22	4	13	7	16	7	23	−4
	M_1	10.86	19	6	18	−0	27	0	28	−2	21	−2	37	1	29	−10	34	1	50	−1	55	4	44	5	48	6	57	−2
	V	10.77	3	2	3	6	7	−6	5	−1	8	−2	3	−10	10	−3	18	−2	16	5	20	6	11	2	24	5	12	7
	VI	10.89	7	2	9	7	5	0	2	−9	5	3	8	−6	11	−7	20	−2	18	1	23	6	15	5	22	7	16	2
	VII	11.13	8	6	12	1	8	2	9	−4	9	−7	5	−1	12	−10	12	4	16	3	19	3	9	3	20	8	16	−2
	M_2	10.94	18	4	24	4	20	−1	16	−3	22	−3	16	−5	33	−7	51	−1	50	3	62	5	35	3	64	6	44	2
	I	10.98	14	7	2	2	3	−4	5	−5	6	−6	6	2	6	−13	3	12	12	−5	11	5	5	7	11	4	9	3
	II	11.17	5	6	5	3	7	−3	13	−2	5	−5	4	7	7	−11	12	5	18	−4	14	8	12	2	7	6	9	−3
	III	10.94	6	2	2	−2	9	−1	3	−2	4	−2	12	−5	4	−4	7	2	6	−3	15	8	4	4	8	7	22	−3
	M_1	10.99	25	6	9	2	19	−2	21	−2	15	−4	22	−1	17	−10	22	6	36	−3	40	8	21	4	26	5	40	−2
	V	10.90	6	1	4	1	4	−0	8	−0	3	−6	0	[−9]	6	−3	18	−4	12	2	15	12	8	1	15	2	8	5
	VI	11.12	5	3	5	9	1	4	3	2	6	−5	7	−4	3	[−9]	12	−4	13	5	14	4	13	2	16	4	12	1
	VII	11.21	7	7	6	6	7	−12	3	1	6	−3	2	[0]	9	−9	5	3	16	7	8	1	8	7	9	4	11	0
	M_3	11.06	18	4	15	6	12	−6	14	0	15	−4	9	−2	18	−6	35	−3	41	5	37	7	29	3	40	4	31	2
48° N. 20°–21° W	I	11.48	3	8	8	−4	11	−2	6	−1	9	−4	6	−2	7	−15	8	6	21	2	15	1	13	5	22	3	17	7
	II	11.45	2	5	1	−11	6	−1	12	−1	6	−5	9	2	7	−11	21	3	21	−3	23	8	10	9	11	1	13	−1
	III	11.46	3	−4	5	−2	5	2	13	−4	6	−0	13	−3	9	−6	9	−0	19	2	17	7	15	5	20	4	22	−7
	M_1	11.46	8	3	14	−3	22	−1	31	−2	21	−3	28	−1	23	−10	38	3	61	0	55	6	38	6	53	3	52	−1
	V	11.18	1	8	1	18	11	−7	4	5	5	−2	2	−7	6	−5	17	−6	22	1	17	10	15	−0	17	6	8	4
	VI	11.38	3	3	5	8	3	8	2	[−4]	9	2	11	−3	14	−14	20	2	14	0	20	−1	23	0	22	8	20	2
	VII	11.60	4	6	8	4	9	−9	5	6	8	−4	6	−6	7	−9	19	3	20	1	20	5	16	6	24	7	20	1
	M_2	11.37	8	6	14	8	23	−6	11	3	22	−1	19	−4	27	−11	56	0	56	1	57	5	54	2	63	7	48	2
48° N. 22°–23° W.	I	11.57	12	0	8	−7	7	−1	8	3	5	−4	6	2	12	−19	9	−3	23	2	12	2	14	6	22	5	18	8
	II	11.50	4	−2	4	−10	9	−3	13	3	2	1	10	2	7	−14	22	−1	25	−4	24	7	17	4	11	3	18	1
	III	11.56	6	−2	10	−4	10	−4	12	−3	9	0	16	−4	11	0	14	−3	22	−1	22	8	16	5	19	4	27	−4
	M_1	11.54	22	1	22	−6	26	−3	33	1	16	−1	32	−1	30	−10	45	−2	70	−1	58	7	47	5	52	4	63	1
	V	11.37	0		9	1	7	−1	8	−1	8	1	3	−8	8	−5	23	−12	24	4	23	8	15	0	24	7	11	7
	VI	11.48	4	4	9	7	6	6	1	[0]	8	7	9	−9	11	−15	21	−6	23	1	27	4	24	2	23	6	22	3
	VII	11.71	7	6	11	7	9	−9	11	1	10	−4	5	−3	11	−11	20	−1	24	−1	24	9	19	9	22	7	24	3
	M_2	11.51	11	6	29	5	22	−2	20	1	26	1	17	−7	30	−11	64	−7	71	1	74	7	58	4	69	7	57	4
48° N. 24°–25° W.	I	11.57	11	−2	5	−6	6	−3	6	0	10	−1	8	−0	6	−28	6	−4	15	6	9	4	8	10	10	9	11	6
	II	11.63	4	−4	3	−15	9	−2	12	2	3	12	6	1	8	−15	11	0	14	−6	17	6	11	3	11	1	13	−1
	III	11.46	9	−2	4	−5	9	−4	9	−1	4	−3	10	−6	9	−7	12	−3	13	4	19	11	6	8	12	8	25	−6
	M_1	11.53	24	−2	12	−8	24	−3	27	1	17	1	24	−2	23	−15	29	−2	42	2	45	8	25	7	33	6	49	−2

Feld	Dekade	Mittel 1900-10	1898		1899		1900		1901		1902		1903		1904	
47° N. 26°–27° W.	V	11.35	6	10	7	−1	7	−6	6	1	7	5	3	−7	9	−8
	VI	11.55	7	3	3	8	3	[9]	0	[−1]	9	2	10	−12	7	−12
	VII	11.67	5	8	12	3	8	1	5	−7	4	1	5	−7	7	−9
	M_2	11.49	18	7	22	3	18	1	11	−2	20	3	18	−9	23	−9
	I	12.06	2	−1	8	−6	8	−4	4	−1	9	−2	3	[−3]	5	−9
	II	11.98	1	10	1	−5	7	−0	13	2	9	3	8	−2	9	−15
	III	11.87	1	1	7	−1	5	2	10	−8	5	8	6	−8	7	−12
	M_1	11.96	4	3	16	−4	20	−1	27	−2	23	2	17	−4	21	−13
	V	11.75	2	7	5	8	8	4	3	−8	11	0	6	−8	8	−7
	VI	12.01	4	5	8	−0	3	7	0	[−0]	5	4	10	−12	9	−11
	VII	12.19	0	−2	6	−6	4	11	9	−5	7	2	4	−6	9	−13
	M_2	11.95	6	6	19	1	15	6	12	−4	23	1	20	−9	26	−10
47° N. [illegible]°–29° W.	I	12.12	7	−9	7	−4	6	−8	8	5	6	−7	7	−8	6	−14
	II	11.71	2	3	3	−11	6	−9	19	5	6	7	9	−1	8	−14
	III	11.78	5	0	6	−2	9	2	10	−2	8	−4	11	−13	6	−8
	M_1	11.86	14	−3	16	−4	21	−4	37	3	20	−2	27	−8	20	−12
	V	11.90	3	8	4	−1	5	6	7	−0	3	4	2	−14	10	−10
	VI	12.07	2	[12]	5	6	5	13	2	−6	7	−2	10	−12	13	−15
	VII	12.46	9	5	11	−3	8	5	9	−6	9	−1	4	−12	10	−8
	M_2	12.15	14	8	20	1	18	8	18	−3	19	0	16	−12	33	−11
	I	12.07	12	−9	13	−3	6	−1	4	1	5	4	7	−7	5	−25
	II	11.83	6	2	3	−12	4	10	9	5	6	7	9	−4	6	−10
	III	11.93	8	3	4	−14	6	2	16	4	5	−6	12	−5	10	−15
	M_1	11.92	26	−2	20	−6	16	3	29	4	16	2	28	−5	21	−16
	V	11.63	7	15	3	4	6	0	4	1	4	−2	1	[−13]	5	−9
	[illegible]	12.04	3	5	2	−0	3	15	1	[4]	5	8	5	−12	5	−12
	[illegible]	12.43	9	6	8	6	7	6	4	−4	6	1	3	−13	5	−4
	[illegible]	[illegible]	19	10	13	6	16	6	9	1	15	3	9	−10	15	−8
	[illegible]	[illegible]	[illegible]		5	−9	9	−6	6	2	7	1	2	[−8]	9	−15
	[illegible]	[illegible]	[illegible]		2	−10	6	3	8	4	6	5	6	−15	7	−22
	[illegible]	[illegible]	[illegible]	4	4	−1	4	−1	12	2	5	−3	5	−7	5	−17
	[illegible]	[illegible]	[illegible]	4	11	−6	19	−2	26	3	18	1	13	−11	21	−18

Feld	Dekade	1905		1906		1907		1908		1909		1910	
47° N. 26°–27° W.	V	20	−12	14	1	20	14	9	2	18	4	7	4
	VI	17	−8	11	1	21	7	19	4	18	7	15	3
	VII	7	−3	19	−1	18	7	11	6	17	6	19	5
	M_2	44	−9	44	1	59	9	39	5	53	6	41	5
	I	10	−1	19	−1	11	9	12	5	19	2	13	4
	II	17	−2	24	−2	20	12	15	8	11	0	19	−4
	III	12	−1	14	−1	21	12	16	6	19	6	17	−3
	M_1	39	−1	57	−1	52	11	43	7	49	4	49	−2
	V	16	−6	18	−3	13	13	13	4	19	4	10	6
	VI	18	−8	19	−2	16	9	21	3	20	7	21	3
	VII	16	−3	14	−5	21	8	18	1	22	3	20	7
	M_2	50	−5	51	−3	50	11	52	3	61	5	51	6
47° N. [illegible]°–29° W.	I	8	1	23	1	12	11	10	6	18	8	17	6
	II	17	2	20	−9	23	15	17	5	12	6	15	−7
	III	17	3	16	3	29	10	15	7	15	10	25	−7
	M_1	42	2	59	−1	64	12	42	6	45	8	57	−3
	V	28	−9	19	−2	22	10	11	7	22	3	10	6
	VI	21	−7	24	6	24	8	21	5	20	7	17	3
	VII	10	−4	24	2	22	10	17	7	20	2	20	6
	M_2	59	−8	67	2	66	9	49	6	62	4	47	5
	I	4	1	8	1	6	8	4	14	11	−0	12	4
	II	11	2	9	−26	11	7	15	7	7	7	12	−3
	III	8	−2	12	4	11	6	5	10	8	10	14	−8
	M_1	23	0	29	−6	28	7	24	8	26	5	38	−2
	V	12	−15	14	−6	15	9	7	14	14	9	6	12
	[illegible]	11	−10	7	2	12	2	10	−1	14	9	8	−2
	[illegible]	2	−2	14	4	9	−4	5	8	11	4	5	6
	[illegible]	25	−13	35	−0	36	3	22	6	39	7	19	4
	[illegible]	7	3	17	1	14	6	12	8	15	4	13	4
	[illegible]	10	4	20	−5	17	11	10	19	10	−4	15	−1
	[illegible]	11	1	12	3	19	7	12	13	16	5	5	−1
	[illegible]	28	2	49	−1	50	8	34	13	41	3	33	1

45° N. 36°–37° W.

44° N. 36°–37° W.

1	20	4	4	4	−0	5	2	5	−2	4	−16	7	−22	13	−6	14	5	15	7	9	11	17	9	9	13
2	6	4	1	3	4	3	1	5	11	9	−15	8	−16	18	−10	15	5	14	−1	21	7	15	11	16	4
1	−6	6	−8	7	5	8	−1	8	6	4	−7	6	−9	11	0	17	−1	17	−0	14	2	17	2	15	3
4	7	14	−1	14	4	16	1	18	5	17	−13	21	−16	44	−7	46	3	46	2	44	7	49	7	40	6
4	−30	16	−8	4	−5	5	3	9	−1	5	−12	7	−11	7	1	22	−1	16	6	10	11	22	3	18	7
3	−2	2	−11	5	3	19	2	8	4	11	−3	3	−15	17	3	15	−7	17	5	20	13	11	3	19	−9
3	9	4	−8	12	5	10	5	6	−7	5	−8	9	−23	21	4	17	−0	24	3	13	15	13	9	23	−3
10	−10	22	−7	21	2	34	2	23	−1	21	−6	19	−17	45	2	54	−2	57	4	43	13	46	5	60	−2
2	17	5	−5	7	8	15	−3	4	6	4	−10	10	−14	20	−13	23	−6	27	10	14	13	23	6	14	3
3	7	4	−1	3	14	3	7	7	8	8	−19	11	−15	17	−8	16	2	19	1	19	6	16	8	18	−4
8	0	9	−1	5	12	7	−3	8	−0	5	−13	11	−10	5	3	25	−4	18	6	16	5	20	6	13	−0
13	7	18	−0	15	11	25	−2	19	6	17	−14	32	−12	44	−10	64	−2	64	7	49	9	59	7	45	0
6	10	8	−2	12	−5	6	1	6	9	3	−5	9	−17	6	−4	17	−1	15	4	9	2	17	8	13	8
0		0		5	5	14	8	3	0	8	−8	6	−17	14	1	20	−1	17	13	11	5	16	−1	18	−3
1	9	8	1	3	6	7	7	4	−6	5	−7	5	−29	12	2	12	4	16	6	17	14	16	7	9	−4
7	11	16	0	20	−1	27	5	13	2	16	−8	20	−20	32	−0	49	−0	48	8	37	8	49	5	40	0
1	13	4	5	7	12	2	−2	6	1	4	−16	3	−10	13	−14	16	−1	16	12	11	8	20	7	13	4
2	8	4	−5	6	6	4	3	8	5	7	−11	13	−18	15	−8	9	9	13	3	17	7	16	6	17	−2
6	−1	3	−2	6	4	9	2	8	−3	6	−10	8	−8	12	−2	14	−1	19	8	10	6	17	1	14	3
9	4	11	−1	19	7	15	3	22	1	17	−12	24	−13	40	−8	39	1	48	8	38	7	53	4	44	1
4	6	36	−17	6	1	3	−3	7	5	8	−7	7	−13	10	−1	18	−3	13	−0	11	9	18	8	12	5
2	−17	4	−4	3	5	15	8	8	−0	12	−7	5	−8	14	−5	11	−15	15	8	12	11	6	1	21	2
5	−10	5	−6	14	6	4	2	10	−2	4	−17	11	−18	21	8	14	−1	18	−5	13	21	14	12	15	−7
11	−6	45	−12	23	3	24	4	25	−0	24	−9	23	−15	25	1	43	−5	46	−0	36	13	38	9	48	−1
3	10	8	1	4	−3	9	−3	7	7	2	[−20]	8	−8	17	−11	21	3	24	13	26	8	20	8	12	6
3	[10]	3	−16	5	6	3	4	5	6	8	−15	6	−10	15	−6	14	5	11	5	16	2	12	5	11	−2
5	−6	11	−0	5	6	4	−0	10	−1	3	−6	7	−11	6	−6	25	1	13	8	15	8	18	−3	9	3
21	6	22	−1	14	5	16	−2	22	4	13	−13	21	−9	38	−9	60	3	48	9	57	6	50	3	32	3
3	−6	4	−29	5	−4	4	−4	6	7	6	−8	8	−10	3	0	9	−3	8	−0	6	12	10	3	9	7
0		1	[−7]	2	−1	6	12	2	−1	3	−8	3	−15	6	2	18	−6	11	5	6	13	12	5	14	−6
0		7	−5	4	−1	5	4	3	4	5	−9	3	−22	9	−2	8	12	13	2	9	19	12	1	6	−7
3	−3	12	−13	11	−2	15	4	11	6	14	−8	14	−13	18	−1	35	−2	32	2	21	15	34	3	29	−3
0		4	9	4	11	1	−2	8	6	2	−13	4	−9	11	−20	7	4	10	9	4	−1	13	6	8	5
2	[5]	4	[−7]	4	[3]	2	[−1]	3	2	5	−13	6	−11	10	−6	10	10	10	2	11	9	13	5	15	−6
2	[0]	6	1	8	−3	8	3	7	−6	3	−7	5	0	12	−2	4	7	13	2	10	5	12	6	8	−7
4	0	14	4	16	1	11	4	18	−0	10	−11	13	−5	33	−10	21	7	33	4	25	7	38	5	31	−1

	8	−4	8	−11	3	6	5	12	7	−15	5	10	12	−16	19	19	18	−4	14	−11	16	3	9	6
	6	−8	2	−1	9	12	5	−2	10	−27	7	−3	9	−17	11	12	18	19	13	−4	13	−4	13	15
	7	−16	7	−6	3	3	7	6	2	2	10	−14	16	−0	11	6	23	−1	9	14	7	−4	13	−4
	19	−7	17	−6	17	8	17	6	19	−20	22	−5	37	−8	41	15	59	5	36	−1	36	−0	35	6
	6	−1	6	17	18	1	8	−0	6	−37	6	10	12	−5	16	7	26	9	22	−18	13	12	10	4
	4	−15	6	9	5	−11	3	13	4	−17	9	1	18	−4	15	−10	11	14	19	11	16	−5	7	−0
	8	−17	0	[8]	3	18	7	−1	8	−15	8	9	10	−4	20	5	15	15	9	−24	18	−8	11	−2
	18	−10	12	12	26	−2	16	2	18	−22	23	7	40	−4	51	3	52	11	50	−8	47	−0	30	1
	1	−14	4	−2	6	−10	4	20	7	−47	0	[−9]	5	8	9	28	9	15	7	−16	5	14	4	−2
	3	−4	1	33	5	10	2	−1	2	−27	4	−4	6	−26	9	2	7	7	9	9	12	−1	8	−5
	3	−8	4	−11	2	12	2	1	6	−63	4	−16	8	23	6	13	10	−4	8	34	3	3	16	7
	7	3	9	−2	13	3	8	11	15	−50	8	−9	19	5	24	16	26	6	24	11	20	5	28	3
	1	−41	3	11	2	−1	4	11	0	[−30]	5	4	8	−19	10	17	8	−4	8	16	9	−5	7	−1
	1	19	0	[17]	2	−70	4	12	2	−18	1	−11	9	1	6	7	9	20	14	18	6	9	8	14
	1	20	6	6	3	10	2	15	5	−35	2	−20	1	20	10	12	6	10	7	−22	8	−3	3	7
	3	−1	9	10	7	−16	10	11	7	−27	8	−2	18	−9	26	14	23	8	29	6	23	−1	18	6
	1	−17	6	−4	3	−4	4	1	9	−20	9	−9	4	−3	16	16	6	13	7	15	10	−7	8	2
4[illegible] 40°–43° W.	3	−12	3	14	9	2	4	−7	3	−10	3	−32	9	6	17	6	11	2	10	16	17	6	10	−4
	7	−2	3	4	5	3	5	−9	7	−17	3	−5	10	6	7	18	14	−9	9	20	11	−0	7	−12
	11	−7	12	4	17	1	13	−5	19	−17	15	−11	23	4	40	12	31	−2	26	17	38	1	25	−4
	6	−4	5	15	5	−4	5	−1	3	−8	5	−31	13	−3	11	10	10	−6	7	17	14	11	15	1
	2	−16	7	4	5	−6	8	3	6	−12	4	−3	7	−3	10	2	11	1	12	20	12	7	10	−13
	6	0	5	7	4	−2	5	−16	3	−17	4	6	14	0	12	9	14	6	10	10	14	−1	6	−3
	14	−4	17	8	14	−4	16	−3	12	−12	13	−12	34	−2	33	7	35	1	29	16	40	6	31	−5
	7	−7	10	0	2	3	3	−1	7	−13	10	1	9	6	20	16	17	−1	18	4	13	0	9	−15
43° N. 44°–45° W.	4	−8	2	1	6	17	7	1	9	−8	9	−55	8	12	10	13	13	22	19	7	12	−15	15	5
	3	−20	6	3	4	−12	8	−11	1	−20	9	−20	10	1	12	15	27	8	14	16	11	7	5	12
	14	−9	18	3	12	4	18	−6	17	−12	28	−24	27	6	42	16	57	9	51	8	36	−3	29	−1
	7	−19	6	8	11	−8	8	−3	5	−8	6	−3	16	−5	13	−0	20	9	20	11	17	−0	14	−1
	4	−3	8	6	2	−6	3	−9	2	−16	7	5	15	−1	15	2	11	8	14	12	18	−0	14	−0
	6	7	3	−13	6	1	7	−3	5	−7	13	2	11	−1	20	10	19	10	9	−0	14	2	12	−0
	17	−7	17	3	19	−6	18	−5	12	−10	26	1	42	−4	48	4	50	8	43	9	49	−0	40	−1
	2	3	7	−21	8	−24	8	−3	6	−6	5	−15	17	13	17	13	16	18	14	5	6	19	2	1
43° N. 46°–47° W.	6	−21	3	6	7	12	8	−6	6	6	11	−47	8	−10	9	−3	13	25	11	12	12	−1	15	5
	8	−25	4	11	6	−6	7	7	2	−21	12	−18	12	0	14	−9	20	14	13	13	6	3	6	8
	26	−29	14	−6	21	−7	23	−1	14	−8	28	−29	37	5	40	2	49	19	28	10	24	5	23	5

			8	47	8	9	8	2	8	−19	4	−8	5	15	4	6	8	−18	10	−2	19	−14	12	46	14	−2	11	−7
			6	43	2	8	2	[3]	1	−47	1	−27	1	−37	3	−20	6	40	21	2	8	23	13	58	10	13	12	−8
			8	12	2	−21	2	[−6]	2	40	6	−12	7	−42	8	20	7	31	17	−15	9	−21	9	53	19	7	4	−64
		7	13	31	7	−5	5	−2	11	−12	11	−12	13	−19	15	9	21	14	48	−6	36	−9	34	50	43	5	27	−19
		8	6	−1	5	−27	4	−0	5	−24	5	33	3	−63	4	−2	7	−20	13	24	12	37	10	−43	11	0	3	57
		0	7	23	4	33	1	−55	13	−5	0	[45]	10	−70	3	−35	10	−4	5	28	14	34	10	18	22	−52	10	35
		6	5	27	3	43	4	−61	6	−30	4	65	5	−40	2	16	7	9	14	31	9	12	20	3	9	−59	4	54
		8	18	15	12	10	9	−35	24	−16	9	46	17	−29	9	−10	24	−6	32	26	35	29	40	−7	42	−40	17	43
		5	6	25	4	7	6	−17	10	−25	3	39	3	−59	3	34	10	−18	7	38	23	−4	18	−13	15	−9	15	36
		2	3	42	2	37	1	−18	2	−61	7	22	5	−48	3	45	11	1	19	43	16	−3	11	−7	9	−5	16	32
		2	8	13	6	12	1	−53	6	45	6	52	5	−37	6	35	4	−45	15	18	5	2	13	0	22	−29	7	13
		.20	17	21	12	13	8	−24	18	−7	16	35	13	−48	12	36	25	−17	41	31	44	−6	42	−9	46	−19	38	28
		9.74	3	31	2	11	4	22	3	−50	5	16	6	−6	5	−15	6	−37	14	−1	16	45	8	−12	9	12	1	27
		11.10	9	21	7	−48	1	−5	21	19	0	[13]	7	−27	2	−51	12	−13	5	9	16	55	9	5	16	−16	14	10
		10.92	6	30	3	−42	5	−7	12	27	6	24	5	−45	6	−40	9	8	17	9	9	32	18	−24	15	−2	4	17
	M₁	10.82	18	27	12	−37	10	1	26	17	11	16	18	−27	13	−35	27	−12	36	2	41	43	35	−15	40	−5	19	16
	V	11.51	7	−12	5	−5	3	5	14	1	6	−1	4	−53	2	−5	13	−31	10	−16	21	20	26	28	13	38	15	15
	VI	10.97	7	20	0		5	−9	1	10	4	34	3	−93	1	10	20	−25	19	−4	15	16	9	2	9	25	12	33
	VII	10.94	5	31	6	−19	4	−9	3	31	7	16	5	−76	6	−23	6	1	16	−8	8	11	12	13	25	19	8	26
	M₂	11.01	19	13	11	−11	12	−5	18	11	17	16	12	−71	9	−15	39	−21	45	−7	44	19	47	22	47	26	35	26
5°	I	11.48	2	26	0		5	10	4	−22	5	2	5	−22	6	−12	5	−19	14	0	14	10	12	31	20	9	0	[12]
	II	11.13	12	40	9	1	3	9	6	−6	0	[2]	4	−18	1	−21	17	−4	4	3	13	2	9	21	9	−3	16	15
	III	11.28	4	16	4	−20	4	−32	19	14	6	−2	4	−2	1	27	11	−10	13	4	10	−22	16	11	8	−4	7	15
	M₁	11.30	18	31	13	−8	12	−5	29	4	11	−0	13	−16	8	−8	33	−10	31	2	37	−2	37	19	37	3	23	13
	V	11.45	6	15	5	−26	2	26	8	17	3	−17	3	9	3	−38	12	−39	9	−10	15	7	16	30	15	21	15	−5
	VI	11.01	7	10	1	−56	7	4	4	6	8	−13	5	−32	2	−1	16	−20	18	−30	13	16	12	18	14	33	9	20
	VII	11.14	2	44	8	−7	2	−31	2	29	6	17	6	−31	6	−18	5	−27	12	−3	8	32	13	17	22	10	13	0
	M₂	11.30	15	18	14	−18	11	3	14	17	17	−2	14	−22	11	−20	33	−26	39	−16	36	17	41	23	51	20	37	6
7°	I	12.09	1	4	4	−15	4	−14	5	6	6	−16	9	−17	7	0	4	27	13	−14	12	8	9	2	15	−5	0	[−6]
	II	11.07	10	39	6	−3	3	3	5	12	1	−41	4	−7	3	−40	17	2	6	16	15	22	8	4	12	25	18	11
	III	12.23	5	10	3	3	0	[7]	18	7	3	−4	3	−12	3	−26	13	15	10	4	14	14	11	6	8	−7	7	−4
	M₁	12.12	16	22	13	−8	7	8	28	7	10	−12	16	−13	13	−16	34	6	29	−1	41	13	28	3	35	4	25	−0
	V	12.25	8	−22	3	−46	2	27	7	6	6	−24	3	−19	2	−64	13	8	10	29	13	37	16	2	12	−11	15	8
	VI	12.26	4	20	0		6	27	7	−8	5	−53	4	−40	2	−33	17	23	19	12	16	50	13	23	15	−0	9	5
	VII	12.75	4	12	9	−42	3	−34	2	12	4	−10	7	−50	9	−18	7	20	10	19	10	45	12	−2	19	14	12	6
	M₂	12.49	10	−2	12	−42	11	10	16	−1	15	−31	14	−42	13	−26	37	16	39	17	39	43	41	6	40	3	36	6

	[illegible]	[illegible]	[illegible]		1	−13	6	−2	10	−0	4	20	8	−54	4	−6	2	23	8	22	3	12	9	−13	4	9	3	−12
	[illegible]	[illegible]	[illegible]		2	12	5	−21	9	1	2	13	2	−40	5	−7	10	−15	6	34	5	−25	5	29	10	4	7	26
	[illegible]	[illegible]	[illegible]		4	−15	4	−49	8	−20	4	14	8	−45	1	33	5	29	5	54	14	−42	1	24	11	−8	3	11
	[illegible]	[illegible]	[illegible]		7	−5	15	−17	27	−2	10	21	16	−43	10	1	17	3	19	39	22	−28	15	9	25	1	13	16
	[illegible]	[illegible]	[illegible]		2	−2	5	−2	1	−42	6	28	2	−25	6	7	7	8	3	31	3	−44	2	30	5	3	13	6
	[illegible]	[illegible]	3	—	2	−39	3	−29	2	−9	2	−4	7	26	3	11	4	22	7	−59	7	−10	8	37	10	15	1	1
	[illegible]	[illegible]	[illegible]		3	−0	5	−2	3	35	1	52	4	28	5	−24	9	9	9	−26	10	−12	3	30	12	3	4	11
	[illegible]	13.46	3	20	7	−15	15	−11	6	4	9	9	13	15	14	−6	20	6	19	−33	20	−20	13	30	27	4	18	4
	[illegible]	14.34	1	−2	1	−28	7	17	5	1	4	19	4	−31	7	−22	11	10	14	18	5	−22	13	−12	7	0	5	22
	[illegible]	13.51	0		3	4	3	16	4	−4	1	15	2	−33	3	4	11	−23	12	−10	15	−26	8	16	20	27	10	17
	III	14.24	0		5	−18	2	3	6	11	4	8	6	11	3	−62	9	−8	5	24	18	−9	6	4	12	15	11	4
	M_1	14.11	1	0	9	−13	12	14	15	3	9	15	10	−14	13	−25	31	−8	31	7	38	−19	27	−0	39	16	26	11
	V	13.96	0		2	−10	5	9	1	−10	5	16	2	−29	9	−8	9	11	5	−15	9	−10	3	−10	7	19	12	26
	VI	14.40	2		4	−26	4	4	4	5	5	22	6	1	7	−16	9	6	10	−14	10	9	13	−33	14	11	7	5
	VII	14.31	0		1	−28	4	4	2	17	1	−3	3	2	4	7	13	7	13	−2	12	−5	5	−23	13	−21	4	17
	M_1	14.30	2	27	7	−22	13	5	7	7	11	16	11	−4	20	−9	31	7	28	−9	31	−3	21	−27	34	0	23	16
40° N. 52°–53° W.	I	14.28	3	6	0		6	0	6	22	3	−13	4	−19	9	6	13	−13	16	−2	9	20	11	8	5	−26	7	16
	II	14.90	0		4	−68	5	−6	5	15	3	2	3	17	3	6	10	−26	16	−22	9	−13	9	9	17	14	7	5
	III	14.27	1	−23	4	−33	1	−3	11	17	5	−8	6	−12	3	−4	8	2	6	−7	16	19	11	1	12	20	10	12
	M_2	14.48	4	−4	8	−49	12	−2	22	17	11	−7	13	−8	15	3	31	−14	38	−11	34	−7	31	6	34	11	24	11
	V	14.19	0		3	−50	7	1	3	−2	5	2	2	−24	9	−4	8	5	5	−19	11	−18	3	39	9	1	17	17
	VI	14.64	2		4	−44	2	−1	6	9	4	−15	3	17	7	−40	9	−10	9	−4	11	−12	12	30	14	15	9	12
	VII	14.70	3	16	0		6	4	5	9	7	−5	5	−21	6	−24	11	2	12	−8	14	−11	7	33	15	−7	7	29
	M_3	14.55	5	21	7	−48	15	1	14	7	16	−6	10	−10	22	−22	28	−1	26	−8	36	−14	22	33	38	3	33	17
40° N. 54°–55° W.	I	14.91	3	−4	0		7	1	5	−13	3	−7	3	−11	7	−5	13	10	11	2	7	5	13	−4	12	17	4	6
	II	15.08	3	16	1	−20	4	16	6	−17	3	−14	2	16	3	−24	8	−9	17	7	15	6	9	−1	14	19	9	−0
	III	14.76	2	10	3	−1	2	7	4	−9	2	19	6	−24	3	−62	6	15	10	17	15	7	10	24	10	−0	12	6
	M_1	14.88	8	8	4	−6	13	7	15	−13	8	−3	11	−13	13	−22	27	6	38	9	37	6	32	6	36	13	25	4
	V	14.89	2	−9	1	−59	9	8	4	−9	7	−5	3	19	7	−7	7	−4	4	4	19	3	4	−5	13	−9	9	3
	VI	15.50	3	−15	4	−55	4	0	3	−10	3	12	3	−5	8	6	9	−20	9	7	13	8	12	−4	13	1	12	5
	VII	15.77	3	2	2	−78	3	12	4	5	3	2	1	2	6	−26	13	−3	12	−9	11	5	10	−24	14	12	7	23
	M_2	15.34	8	−1	7	−60	16	6	11	−4	13	−0	7	6	21	−7	29	−7	25	1	43	5	26	−10	40	2	28	9
40° N. 56°–57° W.	I	15.16	3	−15	0		7	8	6	15	2	−9	3	−10	4	11	7	2	11	5	5	−9	11	−20	15	4	9	3
	II	14.37	6	18	2	−23	1	−4	5	−17	2	[8]	4	−9	5	−10	12	5	8	12	9	−13	10	−5	11	14	7	19
	III	14.27	3	11	3	20	1	7	16	2	4	14	8	−10	3	−77	7	10	10	40	10	−10	12	8	11	2	9	15
	M_1	14.71	12	6	5	−1	9	9	27	−1	6	5	15	−11	12	−21	26	4	29	18	24	−13	33	−6	37	6	25	11

Feld	Dekade	Mittel 1900-10	1898		1899		1900		1901		1902		[illegible]		1904		1905		1906		1907		1908		1909		1910	
40° N. 58°–59° W	V	14.65	1	43	4	−9	5	11	1	−27	6	−2	6	3	11	−34	4	5	8	10	17	5	5	34	11	−12	11	6
	VI	15.15	6	39	4	4	1	−11	3	−15	2	−18	3	−5	6	−28	12	9	10	19	6	27	10	4	11	33	13	−13
	VII	15.95	2	6	1	11	4	13	3	−18	7	21	4	−4	7	−12	14	8	10	4	13	14	10	5	13	22	5	−11
	M_3	15.20	9	5	9	−4	10	9	7	−17	15	−13	13	−2	24	−28	30	10	28	11	36	11	25	11	35	15	29	−7
	—	—	—	—	0		5	25	4	−3	3	−11	3	−0	6	−20	2	−15	13	21	7	−2	12	1	11	13	9	−9
					6	−24	3	−13	6	10	4	−2	2	−15	4	−23	12	5	5	27	9	−5	7	22	9	−7	11	1
					2	−14	1	−9	7	−10	5	−31	3	−27	1	−32	12	6	12	40	10	13	11	10	7	22	9	18
					8	−24	9	9	17	−3	12	−17	8	−19	11	−22	26	1	30	30	26	1	30	9	27	8	29	2
					5	22	3	14	1	−9	6	10	3	−24	7	−27	4	40	6	5	15	−7	9	3	11	0	7	−3
					3	24	0	[22]	3	4	3	1	1	17	6	−39	10	19	7	−11	10	−0	8	−4	11	−7	11	−4
					4	3	4	21	2	2	0	20	3	−13	5	1	13	8	6	−20	11	15	9	−19	19	−18	5	2
					12	16	7	21	6	2	18	16	7	−12	18	−23	29	19	19	−8	34	2	26	−6	41	−8	23	−3
					4	13	7	17	5	15	10	−16	6	18	9	−10	3	−15	12	7	9	−11	11	−13	11	−9	7	18
					9	−8	2	−24	11	−6	1	18	7	10	6	−3	14	−8	7	2	12	16	8	−6	10	−23	8	23
					5	−7	2	1	7	−2	4	18	3	−2	2	−54	10	9	11	14	10	19	13	10	8	−35	7	22
					18	−2	11	4	23	0	15	−8	19	8	17	−15	27	−1	30	7	31	9	32	−3	29	−22	22	21
					3	−8	5	−3	1	−21	3	−6	5	40	6	17	6	1	6	−27	14	15	12	−16	14	−10	9	10
					3	−25	3	−8	4	−5	1	0	1	22	3	−17	12	−12	8	27	12	17	8	−26	16	3	11	−1
					1	−62	1	28	2	8	5	−10	5	−0	6	−24	20	−21	10	−4	12	28	7	−41	19	12	7	26
					7	−24	9	−3	7	−2	9	−6	11	20	15	−6	38	−12	24	2	38	20	27	−26	49	4	27	10
					3	6	5	14	7	−3	9	−17	6	−22	8	36	8	−14	16	19	12	7	13	−0	13	−12	7	−8
					5	1	2	8	18	−30	1	−17	7	−16	4	18	16	−12	9	20	15	10	10	24	11	−7	14	2
					5	14	3	−7	7	−34	2	11	6	8	7	36	10	−9	12	−6	19	−3	16	6	9	−4	6	1
					3	7	10	7	32	−25	12	−11	19	−10	19	33	31	−12	37	11	46	4	35	9	33	−8	27	−1
					3	3	4	25	7	−46	6	5	4	65	9	−10	9	−22	5	−27	22	−21	15	−20	19	20	14	31
					6	−42	3	−53	4	−6	2	27	5	44	5	32	12	−31	13	−13	16	6	11	−33	19	−2	17	29
					2	−32	4	23	3	7	7	6	6	8	6	3	18	−12	17	−21	11	4	6	−47	14	16	11	13
					1	−27	11	4	14	−22	15	10	15	36	20	6	39	−19	35	−18	49	−6	31	−29	52	12	42	26
					4	−42	4	17	10	−16	9	−9	9	24	12	−6	15	−11	16	37	21	20	14	−10	14	−25	6	−27
					7	−44	1	−16	8	15	1	16	8	−17	3	−6	16	−11	14	33	20	31	18	11	22	−24	20	−32
					7	1	2	−33	7	0	7	−8	2	−9	6	−23	10	3	32	27	41	23	23	29	16	3	8	−14
					18	−27	7	−2	25	−1	17	−9	24	1	21	−11	41	−6	62	28	62	25	55	12	52	−15	36	−25

	[illegible]	10.89	0	30	7	20	4	71	7	-18	9	0	5	1	6	-29	11	-24	8	-4	27	1	20	2	19	1	18	-1
	[illegible]	10.22	4	40	6	-23	6	20	7	-9	8	8	5	1	8	-1	17	-5	17	-6	22	6	13	-6	23	17	16	21
	[illegible]	11.13	2	6	2	14	5	5	6	-11	8	-4	10	-9	7	37	20	-28	16	-12	20	0	10	-11	17	-15	16	59
	[illegible]	10.68	12	38	15	-21	15	7	20	-13	25	2	20	-3	21	4	48	-18	41	-8	69	3	43	-3	59	3	50	26
	I	7.18	4	42	4	37	9	10	9	-28	10	-16	8	10	12	-12	11	3	19	38	22	-8	10	-3	13	17	9	-10
	II	6.86	11	26	9	29	2	41	15	20	5	-28	6	6	5	-25	14	-8	12	24	10	-1	19	-10	25	12	22	8
	III	6.14	10	15	8	5	5	15	9	2	4	-10	7	-10	3	-13	15	7	33	32	13	-24	23	2	18	1	12	2
	M_1	6.72	25	25	21	26	16	16	33	-17	19	-17	21	3	20	-13	40	-0	64	31	45	-10	52	-5	56	10	43	2
	V	7.33	9	20	7	-6	2	27	8	13	10	-20	7	-2	10	-31	21	-17	7	-4	25	-9	18	-4	19	-13	24	-8
	VI	7.12	5	18	2	44	5	10	3	-11	7	-10	2	34	7	-22	22	5	19	-4	17	10	13	4	26	-9	20	-10
	VII	7.81	6	26	6	3	8	1	7	-5	15	-21	10	20	8	-13	22	-7	17	21	20	-4	12	1	19	-13	12	16
	M_2	7.24	20	2	15	4	15	22	18	4	32	17	19	19	25	-21	65	-4	43	8	62	-0	43	1	64	-10	56	-3
48° N. 8° 00′ W	I	5.10	5	23	8	11	5	5	8	-14	6	-1	10	-1	13	-1	6	-17	18	14	25	3	9	-10	20	14	12	9
	II	4.67	10	-7	15	10	3	22	12	-17	6	-4	10	5	10	-9	11	-21	16	12	20	-7	21	-1	14	14	29	7
	III	4.32	7	1	6	0	7	17	8	-17	6	23	7	-3	6	-15	16	-19	26	7	19	-7	20	1	22	10	10	3
	M_1	4.73	22	0	20	7	15	14	28	-16	18	6	27	1	29	-6	33	-21	60	10	64	-3	50	-3	56	12	51	7
	V	4.38	10	6	7	-1	4	-1	4	-2	10	9	6	14	7	-17	12	-10	12	-12	20	2	18	3	15	2	22	11
	VI	5.38	5	4	4	-4	3	-7	11	12	7	-2	5	30	11	-15	22	-5	9	-6	18	-0	14	3	32	0	21	8
	VII	6.11	5	11	3	-14	5	20	6	-9	10	-10	8	29	8	-9	20	-8	16	-1	18	-11	12	-5	19	-0	10	4
	M_2	5.34	20	-3	14	-8	12	6	21	-9	27	-1	19	27	26	-14	54	7	37	-5	56	-4	44	-1	66	1	53	6

TABLE 2W.—Deviations of the surface temperature from the eleven-year means (1900 to 1910) for the two decade groups for the 10° longitude fields of the northerly route Channel to New York. Deviations are in hundredths of a degree Centigrade.

W.-Lg	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
					I—III Dekade.	3. Februar—4. März.								
10–19°	10.64	54	20	−6	−21	−32	11	−77	31	−8	27	30	50	−5
20–29°	11.67	3	−51	−23	0	−4	−32	−121	−1	−3	86	59	52	−15
−39°	13.02	−4	−86	2	44	19	−93	−169	22	−16	40	114	52	−12
°	12.83	88	−152	−5	39	0	−104	−167	3	91	48	126	−49	29
	12.81	117	−161	5	14	40	−171	−174	−25	105	55	10	24	118
	10.05	−163	−50	64	−90	−102	34	29	−110	115	28	21	−30	44
	11.84	16	−81	6	−3	−13	−61	−115	−13	48	48	60	17	27
	12.28	21	−112	−5	25	14	−103	−160	−0	44	58	78	20	30
					V—VII Dekade.	15. März—13. April.								
			38	−27	−27	−23	−6	−59	3	14	44	18	54	10
			35	13	−11	11	−82	−104	−58	5	82	41	57	46
			9	60	−1	31	−128	−103	−90	25	55	65	57	29
			−34	59	−33	2	−148	−21	4	−14	22	113	65	−39
			−194	14	17	42	−209	−144	−16	13	88	52	46	99
			−252	3	−83	−27	170	6	−147	−23	119	−155	24	115
			−66	20	−23	6	−67	−71	−51	5	68	22	31	43
			−46	37	−7	22	−142	−93	−40	7	62	68	56	34
					Mean value for both decade groups together.									
			−74	13	−13	−4	−64	−98	−32	25	58	41	34	35
			−81	16	0	18	−122	−127	−20	26	60	73	38	32

wo decade groups for the degree Centigrade.

												1908	1909	1910
												30	50	−5
20−29°	11.67	3	−51	−23	0	−4	−32	−121	−1	−3	86	59	52	−15
30−39°	13.02	−4	−86	2	44	19	−93	−169	22	−16	40	114	50	−12
40−49°	12.83	88	−152	−5	39	0	−104	−167	3	91	48	126	−49	29
50−59°	12.81	117	−161	5	14	40	−171	−174	−25	105	55	10	24	118
60−69°	10.05	−163	−50	64	−90	−102	34	29	−110	115	28	21	−30	44
10−69°	11.84	16	−81	6	−3	−13	−61	−115	−13	48	48	60	17	27
29−59°	12.58	51	−112	−5	25	14	−103	−160	−0	44	58	78	20	30

V—VII Dekade. 15. März—13. April.

10−19°	10.74	49	38	−27	−27	−23	−6	−39	3	14	44	18	54	10
20−29°	11.69	66	35	13	−11	11	−82	−104	−58	5	82	41	57	46
30−39°	12.90	60	9	60	−1	31	−128	−103	−90	25	55	65	57	29
40−49°	12.59	57	−34	59	−33	2	−148	−21	4	−14	22	173	65	−39
50−59°	13.07	90	−194	14	17	42	−209	−144	−16	13	88	52	46	99
60−69°	10.58	54	−252	3	−83	−27	170	6	−147	−23	119	−155	24	115
10−69°	11.93	63	−66	20	−23	6	−67	−71	−51	3	68	22	51	43
20−59°	12.57	68	−46	37	−7	20	−140	−93	−40	7	62	68	56	34

Mean value for both decade groups together.

10−69°	11.88	39	−74	13	−13	−4	−64	−92	−32	25	58	41	34	35
20−59°	12.58	60	−81	16	9	18	−122	−127	−20	26	60	73	38	32

TABLE 3W.—Deviations of the surface temperatures from the eleven-year means (1900 to 1910) for each decade (I-III) and for each 10° longitude field of the southerly region from Portugal to 40° west longitude. M gives the mean value for the whole decade group February 3 to March 4. The first column for each year gives the number of observations, the second column the deviations in tenths of a degree Centigrade. The brackets and the numbers in italics have the same significance as in table I-W.

Feld	Dekade	Mittel 1900-10	1898		1899		1900		1901		1902		1903		1904		1905		1906		1907		1908		1909		1910	
10-19° W. 37-38° N.	I	14.31	12	−21	11	9	24	9	51	6	41	2	20	2	12	−5	35	1	11	−6	28	−1	38	−6	16	−5	30	3
	II	14.24	17	7	5	−12	19	11	9	−7	16	−2	45	8	11	0	23	2	37	1	10	−14	39	−4	10	−1	23	6
	III	14.16	27	−1	11	0	8	14	15	4	46	−4	20	9	48	−11	19	−3	23	4	10	−5	35	−8	17	−9	14	9
	M	14.26	56	−4	27	2	51	10	75	4	103	−2	85	6	71	−9	77	0	71	0	48	−4	112	−6	43	−6	67	5
10-19° W. 39-40° N	I	13.50	7	−24	0		18	6	36	−0	17	1	25	3	12	−5	29	2	14	−11	20	−3	40	−3	33	5	28	5
	II	13.49	13	0	4	−14	29	10	17	1	21	−3	29	4	10	−4	26	2	40	−1	13	−9	25	−3	15	2	22	4
	III	13.20	21	−3	12	1	29	3	15	6	33	−2	25	10	51	−8	29	2	19	−1	12	−3	50	−3	16	−8	17	7
	M	13.41	41	−6	16	−4	76	6	68	2	71	−3	79	7	73	−8	84	2	73	−3	45	−5	115	−4	64	0	67	5
10-19° W. 41-42° N.	I	12.90	6	−28	10	−2	26	7	34	−1	3	−6	24	5	14	−2	20	8	14	−6	20	2	27	−3	18	−1	32	2
	II	12.94	10	4	4	−1	16	5	13	−5	19	3	33	5	27	−4	23	10	35	−1	14	−7	39	−1	11	−4	15	1
	III	12.72	29	1	34	2	18	7	8	5	21	−3	20	7	22	−7	21	−1	23	0	11	−1	21	−4	20	−8	10	6
	M	12.86	57	−2	48	−0	60	6	55	−1	43	−1	77	6	63	−5	64	6	72	−3	45	−3	87	−3	49	−4	57	3
10-19° W. 43-44° N.	I	12.10	2	11	13	3	16	4	24	2	5	−6	15	4	8	−9	15	11	16	−4	19	−8	8	0	16	0	23	5
	II	12.13	27	10	6	1	22	3	4	−1	6	3	21	4	35	−5	14	10	18	−4	3	2	34	1	3	−13	0	[2]
	III	11.85	44	9	35	5	9	4	7	−0	21	−7	16	3	21	−3	12	−5	11	4	18	8	22	0	11	5	5	−9
	M	12.08	73	8	54	*13*	47	3	35	1	32	−6	52	4	64	−6	41	6	45	−2	40	−1	64	−0	30	−1	28	2
20-29° W. 37-38° N.	I	15.25	2	7	28	−4	5	3	31	8	22	1	7	−4	9	−4	14	3	0	[4]	2	−3	15	−7	8	−2	13	1
	II	15.26	1	7	4	−6	2	4	19	4	8	2	19	−3	17	−5	23	−3	15	1	0	[4]	33	0	10	−5	0	[1]
	III	14.96	8	2	18	−2	6	2	3	2	2	4	2	−10	10	−15	9	7	10	12	0	[7]	7	−7	12	−1	2	−2
	M	15.24	11	2	50	−4	13	1	53	6	32	1	28	−4	36	−8	46	0	25	4	2	[5]	55	−3	30	−4	15	1
20-29° W. 39-40° N.	I	14.46	2	13	26	−7	13	−4	11	6	21	5	2	−2	6	−9	16	5	2	−6	5	8	5	−8	28	−5	22	10
	II	14.59	4	9	2	−10	9	2	15	4	11	3	23	−1	15	−3	27	−2	10	−6	7	12	44	1	9	−6	1	−3
	III	14.22	8	3	12	−6	10	2	7	11	4	4	4	−2	25	−3	3	7	7	4	1	−29	25	2	4	−3	2	7
	M	14.60	14	4	40	−9	32	−3	33	5	36	3	29	−2	46	−6	46	0	19	−4	13	6	74	−1	41	−6	25	8

TABLE 2W.—Deviations of the surface temperature from the eleven-year means (1900 to 1910) for the two decade groups for the 10° longitude fields of the northerly route Channel to New York. Deviations are in hundredths of a degree Centigrade.

W.-Lg.	Mittel 1900—10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
						I—III Dekade. 3. Februar—4. März.								
10—19°	10.64	54	20	−6	−21	−32	11	−77	31	−8	27	30	50	−5
20—29°	11.67	3	−51	−23	0	−4	−32	−121	−1	−3	86	59	52	−15
30—39°	13.02	−4	−86	2	44	19	−93	−169	22	−16	40	114	52	−12
40—49°	12.83	88	−152	−5	39	0	−104	−167	3	91	48	126	−49	29
50—59°	12.81	117	−161	5	14	40	−171	−174	−25	105	55	10	24	118
60—69°	10.05	−163	−50	64	−90	−102	34	29	−110	115	28	21	−30	44
10—69°	11.84	16	−81	6	−3	−13	−61	−115	−13	48	48	60	17	27
29—59°	12.58	51	−112	−5	25	14	−103	−160	−0	44	58	78	20	30
						V—VII Dekade. 15. März—13. April.								
10—19°	10.74	49	38	−27	−27	−23	−6	−59	3	14	44	18	54	10
20—29°	11.69	66	35	13	−11	11	−82	−104	−58	5	82	41	57	46
30—39°	12.92	60	9	60	−1	31	−128	−103	−90	25	55	65	57	29
40—49°	12.59	57	−34	59	−33	2	−148	−21	4	−14	22	113	65	−39
50—59°	13.07	90	−194	14	17	42	−209	−144	−16	13	88	52	46	99
60—69°	10.58	54	−252	3	−83	−27	170	6	−147	−23	119	−155	24	115
10—69°	11.93	63	−66	20	−23	6	−67	−71	−51	3	68	22	51	43
20—59°	12.57	68	−46	37	−7	22	−142	−93	−40	7	62	68	56	34
						Mean value for both decade groups together.								
10—69°	11.88	39	−74	13	−13	−4	−64	−93	−32	25	58	41	34	35
20—59°	12.58	60	−81	16	9	18	−122	−127	−20	26	60	73	38	32

TABLE 4W.—Deviations of the surface temperatures from the eleven-year means (1900 to 1910) for February and for the period March 16 to April 15 for the Danish fields between 50° and 64° north latitude and between 0° and 40° west longitude. The deviations are given in tenths of a degree Centigrade. The numbers in brackets are untrustworthy on account of too small numbers of observations and are omitted in the computation of the group means.

Breite	Länge	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Februar:															
59° N.	0 u. 1° W.	6.3		3	5	−1	−4	1	−3	−2	−2	4	0	6	−4
	2 „ 3° „	6.7	15	0	11	2	−21	4	−8	4	0	3	2	4	3
	4 „ 5° „	7.4	19	8		1	−5	0	−6	3	1	−1	−4	4	1
	6 „ 7° „	7.8	15	6		5	2	2	0	6	−6	−8	−12	2	−2
	8 „ 9° „	8.2		7		3	5	9	−5	1	−6	−1	−4	1	−8
58° N.	0 „ 1° „	6.5	13	−2	4	−3	3	6	−3	4	−6	3	−4	2	
	2 „ 3° „	6.5	13	−3	−2	−2	−2	9	−5	2	−6	−2	3	5	0
	4 „ 5° „	6.7	11	−2	2	3	11	17	−7	8	−17	−10	−1	−1	
	6 „ 7° „	7.7	15	−5	−8	0	9	10	−8	4	−2	−11	−1	4	
	8 „ 9° „	8.4	−3	0	3	−1	1	24	−5	5	−10	−10	−6	−4	0
58–59° N.	**0–9° W.**	7.2	12	1	2	1	−0	8	−5	4	−5	−3	−3	2	−1
50° N.	10 u. 11° W.	8.0		[11]			−1	0	−2	2	−5	−5	[16]	4	−12
58° N.	10 „ 11° „	8.3	2	0	−2	0	8		−3	4	−9	−13	−3	−1	4
	12 „ 13° „	8.3	5	5	−4	2	14	[−4]	0	10	−14	−6	−3	2	1
	14 „ 15° „	8.0	6	[19]	4	9	7	2	−1	0	−7	−2	−7	8	−11
	16 „ 17° „	8.2	1				7	0	−1	−3	−6	−2	−5	3	−4
57° N.	12 „ 13° „	8.4	−1	−6	4	[−1]	3	5	1	0	−8	−10			
	14 „ 15° „	8.1	1	7	−10	5	3	6	−2	4	−10	−14	[11]	9	
	16 „ 17° „	8.5	3	5	2	4	4	9	−3	4	−4	−12	−2	5	−11
	18 „ 19° „	8.6	7	2	5	[22]	8	−7	−6	−4	−3	−7	−4	5	−7
56° N.	18 „ 19° „	8.4	2	8	9	9	10	3	−1	−2	−7	[−24]		7	
56–59° N.	**10–19° W.**	8.3	3	3	1	5	6	2	−2	2	−7	−8	−4	5	−6

Breite	Länge	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
57° N.	20 u. 21° W.	8.4					[17]	5	−10	−6	−7	−6	−2	4	−5
56° N.	20 „ 21° „	8.8	6	3	7	2	2	−6	−7	−6	−4	5		7	−4
	22 „ 23° „	8.5	8	−3	17	10	7	−3	−10	−5	−6	−3	−2	3	−6
	24 „ 25° „	7.8			4			1	−10	−5	[11]	−7	−8	−5	−10
55° N.	22 „ 23° „	8.8	2	−22	14	4	7	10	−8	−3	−14	−10	−1	7	
	24 „ 25° „	8.3	4	−8	−1	6	13	11	−9	−10	−1	−3	2	5	−8
	26 „ 27° „	7.5			[10]		8	4	[−17]	−15	−2	[9]	1	−3	−6
54° N.	26 „ 27° „	7.9	3	−9	7	4	9	9	−9	−9	−4	−5	[5]	4	
	28 „ 29° „	7.2	11	7	4	[−8]	11	7	−4	−18	2	4	−1	6	−6
53° N.	26 „ 27° „	8.1		12	14	9	12	1	[−21]	−6	−3	12	[−6]		
	28 „ 29° „	7.6	6	−5	7	2	9	−2	−14	−15	−11	[14]	5	1	
53 57° N.	20–29° W.	8.1	6	−3	8	5	9	3	−9	−9	−5	−1	−1	3	−6
53° N.	30 u. 31° W.	6.7	14	−6	2	[−3]	9	−4	−10	−4	−6	3	6	1	6
	32 „ 33° „	6.1					8	8	−12	−6	[−1]	[4]	5	[−11]	[−1]
52° N.	30 „ 31° „	7.6	1	−11	[−14]	5	0	−7	−20	−3	−11	14	7	11	
	32 „ 33° „	6.9	14	4	7	15	0	8	−13	−9	−14	−3	2	0	7
51° N.	32 „ 33° „	8.9	−8	−21	10	2	−1	14	−21	−10		−3	1	10	
	34 „ 35° „	8.2	3	−6	1	14	27	0	−15	−11		−10	−2	1	9
	36 „ 37° „	7.5			[12]		10	−16	−5	−5	−29	−22	8	17	18
50° N	34 „ 35° „	9.7	−8	7	8	1	19	−10	−6	−3	−7	1	−1	−1	
	36 „ 37° „	9.1	−5	[22]	11	3	8	0	−24	−1	1	−13	22		−14
	38 „ 39° „	9.5	−7			−6	11	−5	3	4		−22	9	−2	9
50–53° N.	30–39° W.	8.0	1	−6	7	5	9	−1	−12	−5	−11	−6	6	5	6
60° N.	2–5° W.	7.0	0	−6	−7	−22	10	7	−1	10	−3	0	7	3	0
62° N.	6–15° W.	6.7	4	4	1	2	5	−1	5	2	−10	1	−1	−1	−2
63° N.	17–22° W.	5.6	−6	−9	−13	8	5	3	−1	5	−2	−10	−2	1	4
56° N.	0–2° W.	5.6	1	5	−4	−4		4	3	1	−4	−1	2	6	−1

TABLE 4W.—Deviations of the surface temperatures from the eleven-year means (1900 to 1910) for February and for the period March 16 to April 15 for the Danish fields between 50° and 64° north latitude and between 0° and 40° west longitude. The deviations are given in tenths of a degree Centigrade. The numbers in brackets are untrustworthy on account of too small numbers of observations and are omitted in the computation of the group means.

Breite	Länge	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Februar:															
59° N.	0 u. 1° W.	6.3		3	5	−1	−4	1	−3	−2	−2	4	0	6	−4
	2 „ 3° „	6.7	15	0	11	2	−21	4	−8	4	0	3	2	4	3
	4 „ 5° „	7.4	19	8		1	−5	0	−6	3	1	−1	−4	4	1
	6 „ 7° „	7.8	15	6		5	2	2	0	6	−6	−8	−12	2	−2
	8 „ 9° „	8.2		7		3	5	9	−5	1	−6	−1	−4	1	−8
58° N.	0 „ 1° „	6.5	13	−2	4	−3	3	6	−3	4	−6	3	−4	2	
	2 „ 3° „	6.5	13	−3	−2	−2	−2	9	−5	2	−6	−2	3	5	0
	4 „ 5° „	6.7	11	−2	2	3	11	17	−7	8	−17	−10	−1	−1	
	6 „ 7° „	7.7	15	−5	−8	0	9	10	−8	4	−2	−11	−1	4	
	8 „ 9° „	8.4	−3	0	3	−1	1	24	−5	5	−10	−10	−6	−4	0
58–59° N.	**0–9° W.**	7.2	12	1	2	1	−0	8	−5	4	−5	−9	−3	2	−1
50° N.	10 u. 11° W.	8.0		[11]			−1	0	−2	2	−5	−5	[16]	4	−12
58° N.	10 „ 11° „	8.3	2	0	−2	0	8		−3	4	−9	−13	−3	−1	4
	12 „ 13° „	8.3	5	5	−4	2	14	[−4]	0	10	−14	−6	−3	2	1
	14 „ 15° „	8.0	6	[19]	4	9	7	2	−1	0	−7	−2	−7	8	−11
	16 „ 17° „	8.2	1				7	0	−1	−3	−6	−2	−5	3	−4
57° N.	12 „ 13° „	8.4	−1	−6	4	[−1]	3	5	1	0	−8	−10			
	14 „ 15° „	8.1	1	7	−10	5	3	6	−2	4	−10	−14	[11]	9	
	16 „ 17° „	8.5	3	5	2	4	4	9	−3	4	−4	−12	−2	5	−11
	18 „ 19° „	8.6	7	2	5	[22]	8	−7	−6	−4	−3	−7	−4	5	−7
56° N.	18 „ 19° „	8.4	2	8	9	9	10	3	−1	−2	−7	[−24]		7	
56–59° N.	**10–19° W.**	8.3	3	3	1	5	6	2	−2	2	−7	−8	−4	5	−6

eite	Länge	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
N.	26 u. 27° W.	8.4	0	13	17	−3	3	0	−11	−9	[−6]	4	4	−7	[3]
	28 „ 29° „	7.8	−6	16	26	0	1	−7	−17	−11	−2	3	0	6	5
	28 „ 29° „	8.0	−1	10	11	4	8	16	−21	−8	−11	−13	−5	7	[7]
N.	20–29° W.	8.4	−0	11	13	3	3	−2	−10	−10	−2	2	−0	3	2
	30 u. 31° W.	7.3		12	30	4	9	−13	−26	−18	10	8	−1	6	−4
	30 „ 31° „	8.0	5	10	17	5	1	[2]	−23	−19	2	−4	0	12	12
	32 „ 33° „	7.7	[17]	12	29	8	8	−17	−25	−3	2	−8	−5	3	9
	30 „ 31° „	9.1	−4	11	14	8	5	−9	−31	−6	16	1	8	5	[−8]
	32 „ 33° „	8.8	2	12	10	2	7	−12	−8	−5	−8	−10	5	8	12
	34 „ 35° „	8.7		−2	19	7	11	−6	−22	−13	−9	4	2	−1	10
	32 „ 33° „	10.0	4	4	11	4	2	−17	−13	−7	6	−2	8	4	4
	34 „ 35° „	9.5	0	14	16	6	5	−16	−7	−11	7	−2	3	1	3
	36 „ 37° „	9.4		−10	14	2	13	−12	−29	−16	12	12	5	[−10]	12
N.	30–39° W.	8.7	1	7	18	5	7	−13	−20	−11	4	−0	3	4	8
N.	16 u. 17° W.	6.5	−5	1	−2	−8	−2		5	−11	9	−5	7	7	0
	18 „ 19° „	6.4	8	−5	−3	−1	2	3	3	−7	1	−3	0	3	7
	20 „ 21° „	5.6	15	3	1	0	−2	−6	6	2	−11	−2	−2	4	8
63° N.	16–21° W.	6.2	6	−0	−2	−3	−1	−1	5	−5	−0	−3	2	5	5
62° N.	6 u. 7° W.	6.2	−7	−6	0	2	10		−1	2	−9	−9	−1	0	−1
	8 „ 9° „	6.5	−5	3	−8	2	4	3	−5	−7	9	5	4	−7	
61° N	4 „ 5° „	6.7	−6	−3	−0	−1	−5	−1	−6		2	1	−2	8	
	6 „ 7° „	6.0	−3	8	[−25]	18	−3	1	5	8	−6	1	−2	9	−1
	8 „ 9° „	7.5		−4	−3	7	−2	1	−1	−9	−2	0	−8	7	
60° N.	2 „ 3° „	7.3	3	2	−13	−2	1	8	0		−2	−1	−1	4	2
	4 „ 5° „	7.5	−3	−2	−5	2	−1	−2	−3	0	0	−1	−2	3	6
	6 „ 7° „	7.6	0	−3	8	2	−3	−1	−2	1	−2	−1	−1	2	−1
	8 „ 9° „	4.1	0	−5	3	0	0	−3	1	2	−2	2	−1	−4	−2
60–62° N.	2–9° W.	7.0	−3	−1	−3	3	0	1	−1	−0	−1	−0	−2	2	1

62° N.	10 u. 11° W.	7.2	−9	−4	−4	0	0	−1	5		4	1	2	6	
	12 " 13° "	7.1	0	4	−10	−6	0	1	3	3	4	−3	2	5	4
	14 " 15° "	7.1	−5	0	−5	2	2	−1	2	2	3	0	3	3	−15
	16 " 17° "	7.0	4	−5	−4	0	−1	−3	1	3	3	−2	0	2	3
61° N.	10 " 11° "	7.6	$\boxed{5}$	−2	−6	5	2	−2	−4	0	0	−2	−2	5	6
	12 " 13° "	7.6		−4	−4	$\boxed{2}$	1	−3	−2	1	0	3	1	2	2
	14 " 15° "	7.4	7	9	−4	5	−5	−9	0	4	2	1	2	2	1
60° N.	10 " 11° "	7.8	0	−7	1	−1	−3	−3	1	1	1	0	−3	1	2
	12 " 13° "	7.7	−1	−5	4	0	−2	−7	2		−3	2	0	0	1
	14 " 15° "	7.7	−1	−3	2	3	−2	2	2	4	−3	−5	2	1	−2
	16 " 17° "	7.6	5	−5	2	−8	0	0	3	2	2	−7	2	6	−6
	18 " 19° "	7.6	−3	−2	3	$\boxed{7}$	2	−2	1	0	1	2	−3	0	−8
60–62° N.	**10–19° W**	7.5	−0	−3	−2	0	−1	−2	1	2	1	−1	1	3	−1
60° N.	20 u. 21° W.	7.3	0	9	4	5	0		−1	−2		3	0	7	−8
	22 " 23° "	7.1	5	7	7	−5	4	−7	7	−2		0	−5	6	1
	24 " 25° "	7.2	0	−2	3	5	6	−2	1	1	−11	−1	−2	4	−1
	26 " 27° "	6.8		−4	2	8	3		−3		−5	−3	−2	5	2
60° N.	**20–27° W.**	7.1	2	2	4	3	3	−4	1	−1	−7	−0	−2	6	−1
56° N.	**0–2° W**	5.9	6	3	−5	−3	5	0	−3	−1	−3	2	1	5	0

Breite	Länge	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
53° N.	26 u. 27° W.	8.4	0	13	17	−3	3	0	−11	−9	[−6]	4	4	−7	[3]
	28 " 29° "	7.8	−6	16	26	0	1	−7	−17	−11	−2	3	0	6	5
52° N.	28 " 29° "	8.0	−1	10	11	4	8	·16	−21	−8	−11	−13	−5	7	[7]
52–57° N.	20–29° W.	8.4	−0	11	13	3	3	−2	−10	−10	−2	2	−0	3	2
53° N.	30 u. 31° W.	7.3		12	30	4	9	−13	−26	−18	10	8	−1	6	−4
52° N.	30 " 31° "	8.0	5	10	17	5	1	[2]	−23	−19	2	−4	0	12	12
	32 " 33° "	7.7	[17]	12	29	8	8	−17	−25	−3	2	−8	−5	3	9
51° N	30 " 31° "	9.1	−4	11	14	8	5	−9	−31	−6	16	1	8	5	[−8]
	32 " 33° "	8.8	2	12	10	2	7	−12	−8	−5	−8	−10	5	8	12
	34 " 35° "	8.7		−2	19	7	11	−6	−22	−13	−9	4	2	−1	10
50° N	32 " 33° "	10.0	4	4	11	4	2	−17	−13	−7	6	−2	8	4	4
	34 " 35° "	9.5	0	14	16	6	5	−16	−7	−11	7	−2	3	1	3
	36 " 37° "	9.4		−10	14	2	13	−12	−29	−16	12	12	5	[−10]	12
50–53° N.	30–39° W.	8.7	1	7	18	5	7	−13	−20	−11	4	−0	3	4	8
63° N.	16 u. 17° W.	6.5	−5	1	−2	−8	−2		5	−11	9	−5	7	7	0
	18 " 19° "	6.4	8	−5	−3	−1	2	3	3	−7	1	−3	0	3	7
	20 " 21° "	5.6	15	3	1	0	−2	−6	6	2	−11	−2	−2	4	8
63° N.	16–21° W.	6.2	6	−0	−2	−3	−1	−1	5	−5	−0	−3	2	5	5
62° N.	6 u. 7° W.	6.2	−7	−6	0	2	10		−1	2	−9	−9	−1	0	−1
	8 " 9° "	6.5	−5	3	−8	2	4	3	−5	−7	9	5	4	−7	
61° N	4 " 5° "	6.7	−6	−3	−0	−1	−5	−1	−6		2	1	−2	8	
	6 " 7° "	6.0	−3	8	[−25]	18	−3	1	5	8	−6	1	−2	9	−1
	8 " 9° "	7.5		−4	−3	7	−2	1	−1	−9	−2	0	−8	7	
60° N.	2 " 3° "	7.3	3	2	−13	−2	1	8	0		−2	−1	−1	4	2
	4 " 5° "	7.5	−3	−2	−5	2	−1	−2	−3	0	0	−1	−2	3	6
	6 " 7° "	7.6	0	−3	8	2	−3	−1	−2	1	−2	−1	−1	2	−1
	8 " 9° "	7.7	0	−5	3	0	0	−3	1	2	−2	2	−1	−4	−2
60–62° N.	2–9° W.	7.0	−3	−1	−3	3	0	1	−1	−0	−1	−0	−2	2	1

	8.3	9	7	8	2	0	7	5	5	2	−5	−4	1	−3	2	1	−6	12	0	−16
	8.1	6	8	9	6	−3	8	5	9	3	−9	−9	−5	−1	−1	3	−6	1	−4	−5
	8.1	5	8	−2	1	15	13	5	5	−4	−6	−9	−2	2	−1	2	−4	4	0	−16
	8.6	7	12	3	−3	6	13	−2	4	1	−10	−6	−3	0	0	3	1	6	6	−8
	9.7	−1	13	0	4	13	9	4	17	0	−13	0	−5	−6	−8	6	−6	−3	−3	−13
Juni	11.1	10	2	5	6	11	7	−1	12	4	−15	−7	−3	−7	−3	9	0	1	1	−13
Juli	12.4	4	−3	−3	13	2	3	−3	14	2	−5	−10	−3	−7	0	6	3	4	−7	−2
August	12.9	1	−1	1	11	11	1	−5	17	−1	0	−7	−5	−3	3	2	1	10	−5	1
September	12.2	5	−2	4	5	7	4	−4	11	−3	−9	−6	−1	−2	−2	8	11	3	2	4
Oktober	10.9	−4	−9	4	13	7	−1	−11	18	0	−8	3	−6	−3	0	−2	6	7	−5	−8
November	9.7	1	5	15	−3	6	−3	1	2	1	−4	0	−3	−6	5	5	6	−6	0	−4
Dezember	9.2	−3	6	5	2	12	1	0	6	−2	−4	−1	−8	−9	0	1	6	−11	−8	−5
Jahr Januar—Dez.	10.10	2.8	3.8	4.1	4.8	7.3	5.2	−0.5	10.0	0.3	−7.3	−4.7	−3.6	−3.8	−0.4	3.7	1.0	2.3	−1.9	−7.1
„ Sept.—Aug.	10.10		3.8	1.8	5.7	6.0	7.8	0.8	5.8	3.7	−5.6	−6.4	−2.4	−3.6	−2.3	2.9	−0.4		−1.6	−6.9

30—39° W. (50—53° N.)

Januar	7.9	−1	−1	14	2	0	15	−3	6	−6	−13	−11	−1	1	6	5	2	13	−7	−12
Februar	8.0	−2	5	5	1	−6	7	5	9	−1	−12	−5	−11	−6	6	5	6	4	0	−1
März	8.2	3	2	0	7	5	26	4	8	−14	−8	−10	−2	−3	−5	12	−5	1	−6	−22
April	8.9	−1	11	5	2	4	13	2	3	−5	−14	−2	4	−1	−3	−2	8	−1	5	−14
Mai	9.9	0	7	0	6	20	11	−2	16	−19	−10	4	2	−3	−10	6	8	−15	8	−2
Juni	11.2	15	−2	13	10	8	−3	7	7	−4	−12	−15	8	0	−4	12	7	7	−5	−12
Juli	12.4	6	−3	9	26	4	−5	−5	19	−2	−15	−13	0	7	−2	10	9	5	−9	−2
August	13.4	3	3	2	14	16	−11	1	21	−6	−8	−7	−13	−4	12	11	6	6	−5	−3
September	12.5	−11	10	0	18	6	2	−7	15	0	−15	−10	−6	0	4	14	11	5	−2	7
Oktober	11.0	−1	−9	5	3	12	3	1	13	−3	−14	8	−12	−1	−4	1	3	10	−16	−14
November	9.7	−7	16	1	−11	10	−12	−1	−4	5	−3	−8	−10	−1	5	14	10	−8	1	−12
Dezember	8.7	−1	7	−5	−2	8	−13	14	−5	2	−11	3	−4	1	−11	12	8	−7	−18	−3
Jahr Januar—Dez.	10.15	0.3	3.8	4.1	6.3	7.3	2.8	1.3	9.0	−4.4	−11.3	−5.5	−3.8	−0.8	−0.5	8.3	6.1	1.7	−4.5	−7.5
„ Sept.—Aug.	10.15		0.2	6.0	5.8	4.9	7.4	−0.9	8.0	−3.2	−7.3	−8.5	−1.7	−3.4	−0.1	4.4	6.8		−1.6	−8.6

Mean value for the 4 above 10° fields.

Jahr Januar—Dez.	9.88				4.4	5.9	4.7	1.0	4.6	−1.2	−4.5	−2.7	−3.4	−3.2	−0.3	3.0	1.3			
Sept.—Aug.	9.88				4.4	4.8	6.8	1.3	3.0	0.4	−3.1	−3.6	−3.0	−3.0	−2.1	2.8	1.0			

TABLE 5W.—Deviations of the surface temperature from the eleven-year means for the single months for the four Danish 10° longitude fields in the Northeast Atlantic Ocean. Deviations are in tenths of a degree Centigrade. Normal temperatures are computed for the eleven-year period 1900 to 1910.

Monat	Mittel	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913
0–9° W. (58–59° N.)																				
Januar	7.8	−3	2	−13	7	1	1	6	−4	−4	3	−2	0	2	3	1	−4	−3	−4	−4
Februar	7.2	−13	8	0	12	1	2	1	0	8	−5	4	−5	−3	−3	2	−1	1	3	1
März	7.0	−7	5	−3	4	7	0	0	−2	4	2	3	−5	1	−1	−3	4	0	6	2
April	7.3	0	6	−2	4	3	0	1	4	2	1	−5	−2	0	0	4	−1	5	9	4
Mai	8.4	6	14	−3	4	3	−1	10	−5	2	−1	0	−7	−1	−2	−1	2	8	7	3
Juni	10.0	11	6	0	2	9	8	3	−7	−1	3	6	−6	−6	−2	0	5	9	0	8
Juli	11.7	5	3	2	−2	3	13	6	−8	−6	3	9	−5	−9	−2	−1	−1	8	3	7
August	12.3	8	0	12	4	10	10	0	−11	−2	6	3	−2	−12	−4	0	7	12	−7	4
September	11.8	8	0	−1	3	5	6	3	−4	−4	4	1	5	−9	−4	−1	1	3	−9	6
Oktober	10.7	−1	−9	0	6	1	−4	3	−1	0	3	−6	9	−4	7	−3	1	−1	−4	3
November	9.6	−2	−6	7	1	4	−1	0	0	1	−1	−4	1	−3	7	−5	−6	−6	−16	5
Dezember	8.6	−4	1	5	3	6	6	−4	−3	−4	−1	−3	1	−2	7	−8	−2	−1	−11	7
Jahr Januar—Dez.	9.38	0.7	2.5	0.3	4.0	4.4	3.3	2.4	−3.4	−0.3	1.4	0.5	−1.3	−3.8	0.5	−1.2	0.4	2.9	−1.9	3.8
Sept—Aug.	9.38		3.8	−1.8	3.8	4.2	4.1	2.8	−2.6	−0.4	0.4	1.9	−3.7	−1.0	−2.4	1.6	−0.5		1.0	−1.3
10–19° W. (56–59° N.)																				
Januar	8.4	−2	4	−7	1	1	6	4	−5	−1	6	−6	−1	−2	4	−2	−8	3	2	−3
Februar	8.3	−7	7	0	3	3	1	5	6	2	−2	2	−7	−8	−4	5	−6	0	0	1
März	8.2	−2	3	1	6	11	3	2	3	−2	3	−3	−2	0	−5	−1	2	0	1	−3
April	8.4	0	6	1	1	−1	7	4	5	−3	−2	−2	−2	−1	−2	2	−6	6	5	3
Mai	9.2	5	9	1	3	0	7	9	3	−1	−2	0	−9	−1	−4	3	−3	4	4	−2
Juni	10.8	5	−1	−1	4	6	17	−1	2	3	−4	2	−7	−12	−5	7	−7	−3	0	−6
Juli	12.2	4	−4	−4	2	2	16	−2	0	0	0	0	−10	−4	−1	1	1	−3	−2	0
August	12.5	8	2	9	4	11	14	−7	1	0	5	2	−4	−8	−3	−1	5	12	−11	2
September	12.0	11	−2	−3	−2	4	11	0	6	−4	−3	−5	−1	−2	−7	1	2	−4	−3	3
Oktober	10.5	6	9	1	7	3	1	−4	8	1	−6	−2	1	−8	5	−2	2	−1	4	1
November	9.5	1	−4	7	5	4	0	2	3	2	−6	−1	−10	−6	12	1	−5	−6	−4	−1
Dezember	8.9	1	8	−3	6	12	5	−3	3	−3	2	−1	−5	−6	1	−1	−1	−2	−2	3
Jahr Januar—Dez.	9.91	2.5	3.1	0.2	3.3	4.7	7.3	0.8	2.9	−0.5	−0.8	−1.2	−4.8	−4.8	−0.8	1.1	−2.2	0.5	−0.5	−0.2
" Sept.—Aug.	9.91		3.8	0.9	2.2	4.1	7.8	2.6	0.8	1.5	0.0	−1.5	−4.3	−4.1	−3.5	2.1	−1.9		−1.2	−1.1

7°	I	9.4	9	10	8	5	6	−17	13	−3	8	−25	7	17	9	−17	8	12	14	1	14	−4	16	7	20	11	16	18
	II	9.5	5	17	6	15	10	−11	9	−1	4	−9	10	23	12	−19	15	3	17	−14	15	5	14	14	12	19	17	−11
	III	9.7	5	5	4	5	11	−3	6	4	9	3	18	−1	8	−3	11	−13	11	5	22	−3	13	3	16	8	23	−6
	M_1	9.5	19	11	18	9	27	−8	28	−1	21	−9	35	11	29	−14	34	1	42	−4	51	2	43	8	48	13	56	0
	V	9.6	3	0	3	14	7	−11	5	5	8	2	3	−22	10	7	18	−8	16	3	20	8	11	−4	22	7	12	15
	VI	10.1	7	5	9	16	5	9	2	−26	5	5	8	−19	11	−5	21	5	18	−6	23	6	15	11	22	9	16	10
	VII	10.7	8	16	12	10	8	1	9	−8	9	−2	5	3	12	−15	12	8	16	4	19	−4	9	5	20	20	16	−10
	M_2	10.2	18	10	24	14	20	−1	16	−5	22	1	16	−12	33	−5	51	0	50	−0	62	3	35	4	64	11	44	4
9°	I	9.5	13	12	2	10	3	−22	5	−7	6	−29	6	21	6	−21	3	24	12	2	11	−6	5	4	11	18	8	17
	II	9.7	5	26	5	14	7	−16	13	0	5	−12	4	27	7	−27	12	18	12	−10	12	9	12	10	7	9	9	−8
	III	9.9	6	−16	2	15	9	−5	3	−4	4	2	11	−1	2	−10	7	−10	6	17	14	10	4	1	8	4	22	−4
	M_1	9.6	24	8	9	14	19	−10	21	−2	15	−15	21	12	15	−22	22	11	30	0	37	6	21	8	26	11	39	1
	V	10.2	6	15	4	11	4	−13	8	5	3	0	0	[−28]	6	7	18	−11	12	6	15	18	8	−6	15	2	8	19
	VI	10.2	5	−3	5	18	1	−12	3	−15	6	−1	7	−10	3	−8	12	1	13	6	14	7	13	4	16	17	12	12
	VII	10.8	7	21	6	15	7	−5	3	−11	6	−7	2	15	9	−7	5	13	16	9	8	−16	8	7	9	2	11	−9
	M_2	10.4	18	12	15	15	12	−7	14	−4	15	−3	9	−6	18	−2	35	−6	41	7	37	5	29	4	40	6	31	6
1°	I	10.1	3	7	8	−3	11	−26	6	4	9	−19	6	18	7	−21	8	12	20	1	12	−12	13	5	22	13	15	26
	II	10.0	2	45	1	1	6	−12	12	1	6	6	9	25	7	−34	21	13	17	−9	22	7	10	17	11	3	13	−18
	III	10.3	3	−8	5	13	5	3	13	−5	6	−7	13	7	9	−29	9	−6	16	18	17	12	15	11	20	11	22	−14
	M_1	10.1	8	11	14	4	22	−15	31	−0	21	−8	28	16	23	−28	38	8	53	3	51	5	38	11	53	11	50	−3
	V	10.4	1	−14	1	16	11	−14	4	16	5	4	2	−29	6	13	17	−14	22	−5	17	18	15	−6	17	−2	8	18
	VI	10.4	3	19	5	20	3	11	2	−19	9	9	11	−1	14	−19	20	8	14	−2	20	−6	23	−2	22	14	20	12
	VII	11.4	4	8	8	22	9	−4	5	−4	8	7	6	−9	7	−9	19	8	20	−2	20	−1	16	12	24	8	20	−6
	M_2	10.8	8	11	14	23	23	−7	11	1	22	7	19	−7	27	−10	56	−0	56	−3	57	3	54	1	63	8	48	7
3°	I	10.7	11	−6	8	−1	7	−9	8	12	5	−13	6	16	12	−32	9	2	23	−0	10	−17	14	8	22	11	17	22
	II	10.3	4	4	4	27	9	−15	13	13	2	3	10	16	7	−31	22	14	18	−9	23	14	17	16	11	−3	18	−18
	III	10.2	6	−6	10	15	8	−5	12	−5	9	−5	16	4	11	−29	14	−1	19	19	21	16	16	6	19	12	27	−12
	M_1	10.4	21	−3	22	1	24	−10	33	6	16	−7	32	9	30	−31	25	6	60	3	54	9	47	10	52	9	62	−5
	V	10.1	0		9	14	7	−6	8	−4	8	11	3	−25	8	7	23	−21	24	9	23	9	15	−7	24	6	11	19
	VI	10.6	4	6	9	18	6	14	1	−26	8	21	9	−6	11	−18	21	−2	23	−4	27	−3	24	3	23	6	22	17
	VII	11.5	7	3	11	11	9	5	11	−8	10	−8	5	4	11	−12	20	7	24	−6	24	9	19	8	22	3	24	−2
	M_2	10.8	11	8	29	14	22	4	20	−6	26	7	17	−7	30	−9	64	−7	71	−1	74	4	58	2	69	4	57	10
5°	I	10.6	11	−1	5	−9	6	−22	6	12	10	−2	8	6	6	−49	6	7	14	−5	9	3	8	20	10	15	10	16
	II	10.4	4	5	3	−41	9	−11	12	10	3	20	6	15	8	−33	11	11	11	−6	17	4	11	11	11	−5	13	−16
	III	10.2	9	−3	4	2	9	3	9	1	4	−4	10	−12	9	−27	12	−3	13	−16	18	15	6	17	12	13	25	−18
	M_1	10.3	24	0	12	−12	24	−8	27	8	17	3	24	1	23	−35	29	5	38	2	44	8	25	16	33	8	48	−10

	31	4	−3	4	−1	5	4	5	13	4	−24	7	−17	15	−28	14	−1	15	15	9	10	17	8	9	19
	0	4	0	3	10	3	−10	5	12	9	−20	8	−6	18	−7	15	−4	14	−4	21	11	15	18	16	1
	−7	6	−8	7	27	8	−10	8	−7	4	−1	6	−10	11	−1	17	−15	17	−3	14	20	17	−3	15	8
	6	14	−1	14	16	16	−5	18	5	17	−17	21	−11	44	−13	46	−7	46	2	44	15	49	7	40	7
	−20	16	−36	4	−19	5	22	9	−2	5	2	7	−42	7	13	21	−7	15	−3	9	25	22	−2	17	12
	−19	2	−33	5	−7	19	21	8	−6	11	6	3	−27	17	14	11	−7	15	25	20	28	11	0	19	−47
	−7	4	9	11	1	10	18	6	−25	5	−8	9	−18	21	11	16	−7	23	−11	13	28	13	16	23	−7
	−16	22	−26	20	−4	34	18	23	−10	21	0	19	−27	45	12	48	−7	53	1	42	26	46	4	59	−15
	31	5	3	7	12	15	−7	4	25	4	−26	10	−11	22	−38	23	−12	27	20	14	13	23	4	14	20
	15	4	10	3	32	3	−2	7	19	8	−13	11	−27	17	3	16	0	19	−7	19	−1	16	6	18	−11
	−2	9	17	5	33	7	−20	8	−4	5	−7	11	−7	5	8	23	−13	18	−4	16	12	20	3	13	−0
	12	18	15	15	24	25	−10	19	14	17	−12	32	−13	44	−18	64	−7	64	6	49	9	59	6	45	3
	18	8	−39	12	−22	6	15	6	7	3	25	9	−63	6	1	16	−1	13	−7	9	17	17	8	13	21
45° N. 33°–35° W.		0		5	−4	14	33	3	−1	8	0	6	−15	14	15	17	−14	17	29	11	26	16	−27	18	−42
	−29	8	−11	2	31	7	22	4	−10	5	−33	5	−28	12	13	9	−1	16	−9	17	17	16	12	9	−24
	20	16	−18	19	−8	27	25	13	4	16	−6	20	−37	32	12	42	−5	46	7	37	27	49	−0	40	−17
	12	4	7	7	12	2	−1	6	18	4	−32	3	−15	14	−34	16	−14	16	21	11	11	20	14	13	19
	12	4	−3	6	20	4	−16	8	27	7	−13	13	−17	11	−9	9	9	13	−2	17	2	16	2	17	−5
	−22	3	−8	6	14	9	4	8	−16	6	−4	8	−15	2	4	14	−7	19	5	10	21	17	−4	14	−2
	−6	11	−2	19	14	15	2	22	9	17	−14	24	−14	27	−14	39	−7	48	9	38	9	55	3	44	3
	17	36	−54	6	0	5	16	7	5	8	3	7	−64	10	11	17	14	12	−8	8	21	18	−4	10	6
45° N. 35°–37° W.	−38	4	−11	3	−18	15	33	8	7	12	−6	5	−9	14	9	7	−33	13	18	12	22	6	−12	21	−9
	−10	5	3	14	23	4	−10	10	11	4	−46	11	−5	21	33	13	−3	18	−34	13	47	14	23	15	−39
	−8	45	−40	23	7	24	18	25	4	24	−12	23	−27	45	16	37	−2	43	−15	33	27	38	4	46	−20
	−9	8	2	4	27	9	−20	7	21	2	−61	8	−16	17	−23	21	11	24	23	26	−5	20	12	12	31
	27	3	−17	5	18	3	2	5	10	8	−22	6	−5	15	−9	14	16	11	−8	16	1	12	7	11	−9
	−31	11	16	5	0	4	5	10	−12	3	12	7	−26	6	17	25	−3	13	−1	15	12	18	−3	9	−1
	−6	22	9	14	16	16	−11	22	6	13	−17	21	−15	38	−12	60	9	48	8	57	1	50	6	32	9
	−22	4	−84	5	−26	4	16	6	27	6	1	8	−63	3	6	9	−0	7	10	6	14	10	1	9	14
44° N. 36°–37° W.		1	−26	2	−2	6	37	2	2	3	−4	3	−33	6	20	17	−12	11	26	6	33	12	−22	14	−44
		7	−9	3	17	5	12	3	−1	5	−36	3	−10	9	22	6	16	13	−18	9	25	12	−1	6	−27
	−10	12	−31	10	−3	15	23	11	20	14	−10	14	−40	18	19	32	−6	31	4	21	25	34	−8	29	−24
		4	−18	4	19	1	−3	8	24	2	−40	4	17	11	−35	7	−23	10	2	4	6	13	16	8	19
	3	4	−10	4	8	2	−7	3	15	5	−27	6	5	10	8	10	3	10	−9	11	13	13	0	15	−9
	1	6	28	8	5	8	12	7	−15	3	−14	5	−16	12	7	4	14	13	5	10	11	12	8	8	−17
	5	14	4	16	10	11	10	18	5	10	−26	15	1	33	−7	21	−5	33	−1	25	12	38	7	31	−5

Feld	Dekade	Mittel 1900-10	1898		1899		1900		1901		1902		1903		1904		1905		1906		1907		1908		1909		1910	
44° N.	I	12.5	4	28	14	−76	9	−5	6	6	4	26	4	−15	9	−61	5	−3	17	12	15	−2	13	16	19	1	8	25
38°–39	II	11.1	1	4	3	−43	5	−7	12	35	6	8	9	−22	6	−37	12	36	10	−19	18	22	11	19	12	−21	22	−14
W.	III	11.3	1	22	6	−18	5	11	2	20	9	−7	5	−50	8	5	16	36	10	1	19	−37	15	35	18	12	16	−25
	M_1	11.6	6	27	23	−53	19	0	20	24	19	3	18	−30	23	−31	33	28	37	2	52	−7	39	24	49	1	46	−13
	V	10.4	2	−9	7	−1	6	32	6	−29	8	21	4	−42	6	−17	19	−25	18	20	22	16	14	−6	17	10	16	21
	VI	11.9	3	7	5	−5	11	16	6	−1	3	8	6	−37	8	18	17	−6	12	−1	10	13	18	2	13	−6	15	−5
	VII	12.5	1	−45	6	26	4	15	6	−0	7	−2	2	10	12	−12	10	−2	20	1	17	−8	13	5	18	7	13	−14
	M_3	11.5	6	−7	18	7	21	21	18	−9	18	9	12	−31	26	−1	46	−14	50	8	49	6	45	1	48	6	44	2
N.	I	11.2	5	−10	7	−52	7	−6	4	0	5	14	6	−33	1	−71	8	12	14	37	14	12	8	26	13	9	7	−1
11°	II	10.8	5	32	7	−35	2	30	5	16	3	11	11	−46	7	−60	10	35	5	−11	14	32	13	17	7	−16	13	−7
	III	11.0	5	22	8	−37	8	10	3	35	8	−9	4	−40	8	−4	9	28	13	−3	24	−36	10	28	10	1	10	−10
	M_1	11.0	15	15	22	−41	17	7	12	15	16	2	21	−41	16	−37	27	26	32	14	52	−4	31	23	30	1	30	−7
	V	10.7	2	−2	3	26	5	26	15	−23	8	30	4	−8	6	−52	14	−37	15	22	23	−3	17	20	17	−3	12	29
	VI	11.6	5	12	2	21	3	14	2	−6	7	4	5	−33	7	25	14	2	14	−10	11	10	11	−8	15	−6	8	8
	VII	11.5	5	−35	10	40	3	32	4	10	5	−21	5	−26	5	−20	10	−0	20	13	11	−8	12	−3	14	2	7	21
	M_2	11.2	12	−8	15	36	11	24	21	−18	20	8	14	−22	18	−12	38	−13	49	10	45	−2	40	6	46	−2	27	21
	I	12.5	3	8	1	−35	2	22	1	8	5	12	5	1	1	−64	2	4	7	5	3	24	1	−9	2	−31	2	28
	II	10.8	0		2	−8	1	−18	5	28	2	7	2	−10	0	[−12]	4	0	10	−3	5	10	5	24	4	−28	6	2
	III	11.9	0		4	−6	1	−9	5	11	0	11	4	−20	2	−6	2	26	3	18	2	−21	1	26	7	9	3	42
	[illegible]	11.9	3	15	7	−13	4	5	11	14	7	12	11	−8	3	−23	8	4	20	−1	10	5	7	13	13	−11	11	−10
	[illegible]	11.3	0		2	−33	2	22	5	24	1	27	0	[−5]	1	−53	6	−29	5	−15	3	−3	2	−2	5	14	2	16
	[illegible]	11.1	1	−1	0		1	19	2	9	4	27	6	−13	1	−61	3	17	8	−7	6	−4	5	22	6	−2	6	−6
	[illegible]	12.1	0		3	39	3	29	2	−0	2	14	3	9	0	[−66]	9	7	2	−37	3	−8	4	10	7	32	1	13
	[illegible]	11.5	1	−5	5	13	6	27	9	15	7	22	9	−7	2	−60	18	−2	15	−16	12	−6	11	14	18	16	9	−2
	I	12.1	3	19	4	−46	8	−16	4	19	5	−0	4	−6	[illegible]	−43	6	−18	16	40	9	1	10	11	15	−5	9	16
	II	11.7	0		3	−42	2	0	10	30	4	16	5	−40	3	−47	10	27	16	−7	10	27	12	40	10	−33	20	−14
	III	11.0	0		8	5	3	5	6	−18	8	8	3	−56	5	−16	11	43	6	26	15	−27	11	41	15	5	9	−11
	M_1	11.6	3	24	15	−19	13	−7	20	13	17	6	12	−32	19	−35	27	23	38	20	34	−5	33	32	40	−9	38	−6
	V	11.2	1	−42	6	−41	6	19	5	1	7	8	3	−36	5	3	13	−23	14	2	17	−13	9	25	15	−4	14	18
	VI	11.4	1	31	4	−4	9	11	6	19	2	14	4	−44	7	12	12	2	10	−7	15	−5	14	13	13	3	12	19
	VII	12.6	0		6	16	6	−1	6	3	7	−20	5	8	10	23	12	−5	17	8	18	−6	10	11	18	4	8	−26
	M_2	11.8	2	−11	16	−11	21	9	17	8	16	−3	12	20	22	15	37	−10	41	2	50	−9	33	14	46	1	34	−7

	V	10.9	1	31	4	−3	4	−1	5	4	5	13	4	−24	7	−17	15	−28	14	−1	15	15	9	18	17	8	9	19
	VI	12.0	2	0	4	0	3	10	3	−10	5	12	9	−22	8	−6	18	−7	15	−4	14	−4	21	11	15	18	16	1
	VII	12.0	1	−7	6	−8	7	27	8	−10	8	−7	4	−1	6	−10	11	−1	17	−15	17	−3	14	20	17	−3	15	2
	M_2	11.8	4	6	14	−1	14	16	16	−5	18	5	17	−17	21	−11	44	−13	46	−7	46	2	44	15	49	7	40	7
46° N	I	11.6	4	−20	16	−36	4	−19	5	22	9	−2	5	2	7	−42	7	13	21	−7	15	−3	9	25	22	−2	17	12
32°–33°	II	10.9	3	−19	2	−33	5	−7	19	21	8	−6	11	6	3	−27	17	14	11	−7	15	25	20	28	11	0	19	−47
W.	III	11.5	3	−7	4	9	11	1	10	18	6	−25	5	−8	9	−18	21	11	16	−7	23	−11	13	28	13	16	23	−7
	M_1	11.4	10	−16	22	−26	20	−4	34	18	23	−10	21	0	19	−27	45	12	48	−7	53	1	42	26	46	4	59	−15
	V	10.9	2	31	5	3	7	12	15	−7	4	25	4	−26	10	−11	22	−38	23	−12	27	20	14	13	23	4	14	20
	VI	11.5	3	15	4	10	3	32	3	−2	7	19	8	−13	11	−27	17	3	16	0	19	−7	19	−1	16	6	18	−11
	VII	12.4	8	−2	9	17	5	33	7	−20	8	−4	5	−7	11	−7	5	8	25	−13	18	−4	16	12	20	3	13	−0
	M_2	11.4	13	12	18	15	15	24	25	−10	19	14	17	−12	32	−13	44	−18	64	−7	64	6	49	9	59	6	45	3
45° N.	I	12.1	6	18	8	−39	12	−22	6	15	6	7	3	25	9	−63	6	1	16	−1	13	−7	9	17	17	8	13	21
34°–35°	II	10.4	0		0		5	−4	14	33	3	−1	8	0	6	−15	14	15	17	−14	17	29	11	26	16	−27	18	−42
W.	III	11.9	1	−29	8	−11	2	31	7	22	4	−10	5	−33	5	−28	12	13	9	−1	16	−9	17	17	16	12	9	−24
	M_1	11.3	7	20	16	−18	19	−8	27	25	13	4	16	−6	20	−37	32	12	42	−5	46	7	37	27	49	−0	40	−17
	V	10.8	1	12	4	7	7	12	2	−1	6	18	4	−32	3	−15	14	−34	16	−14	16	21	11	11	20	14	13	19
	VI	11.8	2	12	4	−3	6	20	4	−16	8	27	7	−13	13	−17	11	−9	9	9	13	−2	17	2	16	2	17	−5
	VII	12.8	6	−22	3	−8	6	14	9	4	8	−16	6	−4	8	−15	2	4	14	−7	19	5	10	21	17	−4	14	−2
	M_2	11.9	9	−6	11	−2	19	14	15	2	22	9	17	−14	24	−14	27	−14	39	−7	48	9	38	9	55	3	44	3
45° N.	I	11.7	4	17	36	−54	6	0	5	16	7	5	8	3	7	−64	10	11	17	14	12	−8	8	21	18	−4	10	6
36°–37°	II	10.3	2	−38	4	−11	3	−18	15	33	8	7	12	−6	5	−9	14	9	7	−33	13	18	12	22	6	−12	21	−9
W.	III	10.2	5	−10	5	3	14	23	4	−10	10	11	4	−46	11	−5	21	33	13	−3	18	−34	13	47	14	23	15	−39
	M_1	11.0	11	−8	45	−40	23	7	24	18	25	4	24	−12	23	−27	45	16	37	−2	43	−15	33	27	38	4	46	−20
	V	10.1	3	−9	8	2	4	27	9	−20	7	21	2	−61	8	−16	17	−23	21	11	24	23	26	−5	20	12	12	31
	VI	11.3	3	27	3	−17	5	18	3	2	5	10	8	−22	6	−5	15	−9	14	16	11	−8	16	1	12	7	11	−9
	VII	12.0	5	−31	11	16	5	0	4	5	10	−12	3	12	7	−26	6	17	25	−3	13	−1	15	12	18	−3	9	−1
	M_2	11.0	11	−6	22	9	14	16	16	−11	22	6	13	−17	21	−15	38	−12	60	9	48	8	57	1	50	6	32	9
44° N	I	13.2	3	−22	4	−84	5	−26	4	16	6	27	6	1	8	−63	3	6	9	−0	7	10	6	14	10	1	9	14
36°–37°	II	10.7	0		1	−26	2	−2	6	37	2	2	3	−4	3	−33	6	20	17	−12	11	26	6	33	12	−22	14	−44
W.	III	12.3	0		7	−9	3	17	5	12	3	−1	5	−36	3	−10	9	22	6	16	13	−18	9	25	12	−1	6	−27
	M_1	12.0	3	−10	12	−31	10	−3	15	23	11	20	14	−10	14	−40	18	19	32	−6	31	4	21	25	34	−8	29	−24
	V	11.3	0		4	−18	4	19	1	−3	8	24	2	−40	4	17	11	−35	7	−23	10	2	4	6	13	16	8	19
	VI	12.2	2	3	4	−10	4	8	2	−7	3	15	5	−27	6	5	10	8	10	3	10	−9	11	13	13	0	15	−9
	VII	12.8	2	1	6	28	8	5	8	12	7	−15	3	−14	5	−16	12	7	4	14	13	5	10	11	12	8	8	−17
	M_2	12.2	4	5	14	4	16	10	11	10	18	5	10	−26	15	1	33	−7	21	−5	33	−1	25	12	38	7	31	−5

d	Dekade	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
	V	9.5	3 −11	5 −55	6 22	10 28	3 30	3 −37	8 −3	15 −25	12 −52	18 −18	18 33	9 −15	12 37
	VI	9.6	7 −41	5 −18	3 12	1 −36	6 −0	7 17	9 33	19 −30	16 −37	8 31	16 2	14 27	12 −19
	VII	11.2	6 −24	8 −8	4 41	6 1	4 0	5 −14	5 −25	10 3	15 −5	12 −45	8 −1	16 14	8 31
	M_3	10.2	16 −29	18 −23	13 24	17 14	13 6	15 −5	22 4	44 −23	43 −30	38 −17	42 2	39 13	32 13
	I	6.0	7 −1	2	4 −19	10 2	7 0	5 −35	4 −51	5 −15	10 34	12 0	52 8	8 46	3 30
	II	5.9	9 15	5 −46	3 −24	6 49	10 7	2 37	8 −1	9 −52	3 −73	4 72	9 18	13 −25	17 −8
	III	6.2	9 9	3 −62	6 10	3 12	5 4	1 −22	5 −11	6 11	6 −8	10 −40	20 68	13 13	7 −36
	M_1	5.8	28 10	8 −50	13 −5	19 19	22 6	8 −14	17 −14	20 −22	19 6	26 −2	81 25	34 10	27 −10
	V	5.6	7 −9	3 −60	2 26	3 10	4 25	1 −71	6 −16	12 −39	5 3	9 9	15 44	5 −3	10 11
	VI	5.5	5 −39	2 45	3 10	0 [23]	5 5	1 −35	5 4	14 −20	8 −33	8 4	10 30	10 32	11 −19
	VII	6.6	4 −26	5 −15	4 34	3 24	3 34	0 [−64]	4 −29	5 −27	7 13	6 −18	10 16	11 30	8 −11
	M_3	6.0	16 −24	10 −17	9 25	19	12 18	2 −57	15 −14	31 −31	20 −8	23 −1	35 31	26 25	29 −7
	I	11.1	1 18	0	3 −12	7 20	5 23	4 13	4 −55	3 −35	7 34	3 18	2 5	3 −16	7 5
48°	II	11.8	0	3 11	3 16	5 11	2 2	1 −34	1 −68	7 6	11 11	7 32	2 43	13 −41	7 21
	III	11.0	0	7 4	2 −30	6 −21	3 18	6 −29	2 −12	5 50	4 38	6 −50	4 49	7 8	3 −20
	M_1	11.4	1 15	10 −2	8 −7	18 2	10 15	10 −16	7 −47	15 12	22 −23	16 −2	8 35	23 −22	17 6
	V	12.3	0	2 −28	3 7	2 −38	0 [37]	2 −18	3 −30	7 8	3 −3	4 −18	3 41	8 −17	13 30
	VI	11.0	0	1 −8	3 2	2 7	2 −3	7 −17	2 47	4 1	7 −53	7 29	8 2	7 16	4 −31
	VII	13.5	0	4 18	2 35	2 3	4 48	2 −10	5 −2	11 −11	5 18	8 −32	5 3	10 −11	3 −41
	M_3	12.6	0	7 4	8 10	6 −10	6 34	11 −19	10 2	22 −1	15 −20	19 −6	16 9	25 −4	22 5
41° N.	I	11.0	6 4	4 −40	10 2	26 3	3 19	5 −1	9 −33	13 −11	31 21	5 32	14 −22	10 8	9 −16
46° W 47°	II	10.6	0	5 −24	2 −25	4 13	1 30	4 −14	2 −5	12 −20	16 0	12 17	11 29	15 −24	11 −1
	III	10.6	0	6 −33	2 −21	5 −5	3 −22	6 −24	4 0	14 32	6 33	18 −42	20 47	10 −2	10 4
	M_1	10.6	6 7	15 −31	14 −3	35 6	7 4	14 −12	15 −18	39 3	53 18	35 −11	45 22	35 −7	30 −3
	V	8.7	0	4 −52	4 −10	1 −57	6 41	2 −7	7 −1	6 −17	7 −2	14 −15	6 41	16 8	13 19
	VI	11.3	4 2	3 −19	9 −14	2 47	4 33	6 −38	6 12	8 9	12 −45	13 20	13 25	14 −11	12 −39
	VII	11.1	1 −31	3 12	5 −5	6 21	4 −10	5 −7	7 8	15 2	21 −2	14 −21	12 21	11 9	7 −17
	M_3	10.6	5 2	10 −27	18 −10	9 21	14 19	13 −19	20 3	29 −0	40 −14	41 −9	31 27	41 −2	32 −15
41° N	I	7.0	3 61	5 −25	3 4	1 0	4 21	2 −57	5 −28	13 −21	15 34	11 28	9 1	10 20	6 6
48° 49°	II	7.6	8 56	6 9	1 −36	21 23	2 39	5 −7	0 [−31]	4 −7	7 · 12	19 22	8 23	11 −21	9 −16
W.	III	8.3	3 9	5 −15	2 −22	5 10	6 −35	3 −46	9 −37	13 22	10 34	11 −10	19 62	6 −11	11 32
	M_1	7.9	14 44	16 −12	6 −19	27 18	12 −5	10 −31	14 −34	30 −3	32 25	41 12	36 38	27 −7	26 8

	V	7.2	2	63	3	8	5	−24	8	12	4	20	5	10	4	3	8	−18	10	−27	19	−13	12	35	14	−17	11	20
	VI	8.1	6	4	2	24	0	[−33]	1	−51	1	−21	1	−1	3	22	6	5	21	−12	8	24	13	72	10	11	12	−16
	VII	8.7	5	7	2	−12	0	[−39]	2	38	6	−12	7	3	8	23	7	11	17	−14	9	−17	9	50	19	5	4	−43
	M_2	8.2	13	15	7	4	5	−34	11	5	11	−2	13	1	15	18	21	−4	48	−16	36	−10	34	51	43	−2	27	−9
41° N. 50°–51° W	I	7.3	5	36	5	−50	3	16	5	−6	5	6	3	−64	4	25	7	−49	11	8	9	24	8	−47	11	48	3	41
	II	6.6	7	38	4	50	1	−16	13	9	0	[17]	8	−14	3	−39	10	−28	4	18	14	53	10	−37	22	−45	10	7
	III	7.6	5	33	3	39	4	−32	6	−20	4	13	5	−43	2	17	7	35	12	19	9	−3	20	34	9	−33	4	14
	M_1	7.2	18	35	12	5	8	−11	24	−3	9	11	15	−55	9	1	24	−17	27	16	32	28	38	18	42	−20	17	12
	V	6.8	6	27	4	−3	6	−6	10	−24	3	61	3	−38	3	25	10	−46	7	−19	23	12	18	15	15	−13	15	32
	VI	8.2	3	24	2	18	1	8	2	−52	7	8	5	−48	3	68	11	1	19	6	16	−10	11	26	9	−12	16	8
	VII	8.9	8	15	6	28	1	−49	6	49	6	58	5	−11	6	32	4	−36	15	3	5	13	13	−9	22	−10	7	−39
	M_2	8.1	17	20	12	16	8	−18	18	−7	16	38	13	−31	12	40	25	−27	41	2	44	−1	42	8	46	−11	38	6
41° N 52°–53° W	I	7.7	3	10	2	−3	3	−32	3	−20	5	5	4	2	5	−27	6	−59	12	−0	15	51	6	−40	9	31	1	87
	II	7.3	9	49	7	43	1	−36	21	34	0	[26]	6	−39	2	−63	12	3	5	12	10	87	9	60	16	−63	13	−23
	III	8.5	6	41	3	−29	5	−29	12	13	6	28	5	−52	6	−15	9	39	15	6	9	−24	18	34	15	−25	4	24
	M_1	7.8	18	40	12	16	9	−28	36	22	11	20	15	−33	13	−25	27	1	32	6	34	42	33	30	40	−27	18	−8
	V	8.6	7	−13	5	8	3	−13	14	−15	6	19	4	−12	2	39	13	−61	10	−38	21	19	26	36	13	13	15	14
	VI	8.7	7	−3	0		5	3	1	−17	4	43	3	−52	1	33	20	−26	19	−16	15	−1	9	19	9	3	12	12
	VII	9.6	5	6	6	−3	4	6	3	42	7	38	5	−42	6	18	6	−5	16	−24	8	3	12	−6	25	8	8	−33
	M_2	9.0	19	−5	11	4	12	0	18	−8	17	33	12	−34	9	28	39	−36	45	−24	44	7	47	21	47	10	35	2
41° N 54°–55° W	I	7.0	2	50	0		5	−17	4	0	5	14	5	17	6	−42	5	−47	12	−8	13	54	10	−20	20	32	0	[16]
	II	7.7	12	46	9	23	3	−11	6	3	0	[27]	4	−39	1	−37	17	−9	4	−11	11	42	9	45	9	−10	14	1
	III	9.1	4	38	4	−37	4	−40	19	18	6	32	4	−19	1	9	11	20	11	−26	10	−24	16	54	8	−38	7	19
	M_1	8.1	18	44	13	5	12	−25	29	13	11	24	13	−13	8	−42	33	−5	27	−17	34	25	35	31	37	2	21	5
	V	8.5	6	−2	5	−14	2	45	8	−25	3	0	3	15	3	−5	12	−56	9	−15	15	11	16	25	15	−8	15	14
	VI	8.6	7	−3	1	−66	7	−1	4	−11	8	25	5	−9	2	12	16	−28	18	−33	13	7	12	11	14	27	9	0
	VII	10.2	2	−37	8	19	2	−17	2	83	6	29	6	−9	6	5	5	−15	12	−52	8	14	13	−18	22	−5	13	−14
	M_2	8.8	15	−7	14	8	11	5	14	−6	17	25	14	1	11	10	33	−36	39	−32	36	12	41	10	51	8	37	4
41° N 56°–57° W	I	6.9	1	10	4	30	3	−11	5	9	6	−2	9	−16	7	−8	4	−42	10	−6	11	41	7	−6	15	37	0	[5]
	II	6.7	10	41	6	−2	3	11	5	4	1	−47	4	−30	3	−40	17	−2	6	1	15	21	8	15	12	58	16	9
	III	8.6	5	30	3	−2	0	[−19]	18	14	3	33	3	−5	3	−9	13	38	8	−18	14	−37	11	38	8	−21	7	−15
	M_1	7.7	16	31	13	3	6	−10	28	14	10	1	16	−23	13	−20	34	6	24	−11	40	3	26	17	35	26	23	−3
	V	8.2	8	−28	3	−17	2	38	7	−2	6	6	3	51	2	−84	13	−22	10	−1	13	21	16	−2	12	−20	15	15
	VI	7.9	4	22	0		6	22	7	−8	5	19	4	−18	2	−9	17	−9	19	−19	16	21	13	−12	15	11	9	2
	VII	10.2	4	−36	9	−12	3	−29	2	78	4	16	7	−23	9	8	7	−4	10	−53	10	9	12	−12	19	−7	12	18
	M_2	8.7	16	−18	12	−3	11	10	16	1	15	12	14	−2	13	−1	37	−15	39	−25	39	17	41	−8	46	−2	36	14

	I	9.6	0		1		6	−21	10	3	4	17	8	−50	4	−30	2	−21	8	54	3	42	9	−15	4	−3	3	23
	II	9.9	0		2	59	5	−16	9	7	2	4	2	−25	5	−25	10	−23	6	1	4	29	5	41	10	−25	7	32
	III	10.0	0		4	15	3	−57	8	−6	4	21	8	−38	1	1	5	53	3	46	14	−49	1	60	11	−36	3	5
	M_1	9.3	0		7	25	14	−22	27	7	10	21	16	−38	10	−20	17	5	17	39	21	−15	15	13	25	−20	13	29
	V	10.6	0		2	4	5	4	1	−6	6	39	2	−3	6	−4	7	−18	3	−17	3	−78	2	73	5	−3	13	12
	VI	11.0	3	22	2	−40	3	−20	2	−35	2	50	7	53	3	56	4	18	4	−87	7	12	8	33	10	−23	1	−56
	VII	10.8	0		3	−6	5	14	3	32	1	−18	4	−10	5	−18	9	3	9	−41	10	−26	3	53	12	−8	4	19
	M_2	11.2	3	20	7	−17	13	−2	6	−0	9	31	13	22	14	−0	20	−5	16	−51	20	−24	13	41	27	−16	18	4
40° N. 50°–51° W.	I	10.5	1	54	1	−65	7	−15	5	5	4	2	4	−49	7	−17	11	−6	14	56	5	21	13	−30	7	9	5	25
	II	9.7	0		3	6	3	7	4	2	1	−27	2	−18	3	−23	11	−15	11	−20	14	26	8	29	20	14	10	−24
	III	10.2	0		5	9	2	−42	6	13	4	19	6	−28	3	−56	9	41	4	38	18	−30	5	38	12	−11	11	17
	M_1	10.1	1	58	9	−1	12	−13	15	8	9	8	10	−33	13	−26	31	5	29	25	37	−2	26	1	39	4	26	21
	V	10.7	0		2	−20	5	5	1	−57	5	27	2	19	9	−29	9	28	5	−16	9	−38	3	37	7	−4	12	29
	VI	12.4	2	−7	4	−42	4	−9	4	−20	5	34	6	30	7	26	9	−3	10	−33	10	17	13	−12	14	−16	7	−14
	VII	11.1	0		1	−31	4	39	2	39	1	−21	3	−13	4	−1	13	4	13	−29	12	−34	5	13	13	−18	4	18
	M_2	11.6	2	2	7	−32	13	9	7	−6	11	25	11	18	20	−6	31	7	28	−29	31	−20	21	4	34	−14	23	11
40° N. 52°–53° W.	I	9.8	1	51	0		6	1	6	5	3	18	4	−40	9	−10	13	−38	16	39	7	42	11	−29	5	−2	7	14
	II	10.4	0		4	−39	4	−29	5	15	3	−20	2	−0	3	−30	10	−12	12	−24	8	20	9	13	17	31	7	36
	III	11.4	1	−59	4	−13	1	−54	11	21	5	17	6	−7	3	14	8	17	6	19	16	−35	10	35	12	−14	10	−13
	M_1	10.6	4	−4	8	−22	11	−19	22	17	11	9	12	−15	15	−12	31	−17	34	12	31	−1	30	5	34	11	24	10
	V	11.3	0		3	−51	7	−23	3	12	5	17	2	17	9	−33	8	−15	5	8	11	−31	3	63	9	−20	17	3
	VI	12.3	2	−1	4	−48	2	−3	6	−14	4	20	3	31	7	1	9	−18	9	−21	11	−4	12	30	14	−14	9	−15
	VII	11.8	3	−24	0		6	19	5	38	7	15	5	−45	6	−6	11	−2	12	−29	14	−35	7	43	15	−6	7	7
	M_2	11.5	5	−10	7	−46	15	−3	14	14	16	19	10	−7	22	−13	28	−8	26	−16	36	−20	22	43	38	−9	33	−1
40° N. 54°–55° W	I	9.8	1	51	0		7	0	5	−23	3	4	3	−23	7	8	13	−35	11	37	6	2	13	−34	12	32	4	31
	II	10.3	3	51	1	7	3	−13	6	−4	3	−11	0	[−16]	3	−15	8	−27	15	−7	14	27	9	−8	14	50	9	23
	III	10.8	2	42	3	−8	2	−63	4	21	2	26	6	−16	3	−9	6	10	10	28	15	−48	8	47	10	−5	12	8
	M_1	10.2	8	50	4	1	12	−15	15	−3	8	4	9	−15	13	−2	27	−23	36	17	35	−7	30	−5	36	29	25	20
	V	11.0	2	−8	1	−20	9	−3	4	−18	7	26	3	27	7	−28	7	−1	4	0	19	−16	4	28	13	−21	9	5
	VI	12.7	3	20	4	−62	4	3	3	−23	3	48	3	20	8	39	9	−19	9	2	13	−11	12	2	13	−24	12	−36
	VII	11.9	3	7	2	−2	3	21	4	38	3	47	1	−19	6	−49	13	−3	12	−45	11	−17	10	17	14	−7	7	18
	M_2	11.8	8	10	7	−34	16	1	11	1	13	34	7	18	21	−7	29	−8	25	−18	43	−15	26	15	40	−16	28	−7
40° N. 56°–57° W.	I	10.0	1	20	0		7	24	6	−26	2	−7	5	−4	4	14	7	−9	11	26	3	−42	11	−43	15	37	9	30
	II	9.7	6	29	2	28	1	−27	5	−18	0	[38]	1	−7	5	−12	12	2	7	−18	8	11	10	−12	11	47	7	−3
	III	10.6	3	29	3	−8	1	−6	16	−30	4	50	6	31	3	−37	7	−11	10	8	10	−20	12	27	11	−11	9	−0
	M_1	10.5	12	22	5	3	9	9	27	−29	6	30	12	11	12	−15	26	−10	28	4	21	−15	33	−12	37	21	25	6

40° N. 66°–67° W.	V	8.1	6	4	7	−62	4	19	7	7	9	6	5	47	6	0	11	−10	8	−9	27	−12	20	−3	19	−33	18	−12
	VI	7.9	4	18	6	−28	6	−28	7	−10	8	−17	5	−11	8	9	17	3	17	−7	22	8	13	9	23	9	16	25
	VII	9.1	2	−26	2	−14	5	−21	6	−11	8	−3	10	−9	7	34	20	−5	16	−22	20	−4	10	0	17	6	16	34
	M_2	8.3	12	3	15	−44	15	−13	20	−4	25	−4	20	7	21	16	48	−2	41	−12	69	0	43	1	59	−5	50	15
	I	2.8	4	25	4	−2	8	25	9	−23	10	−10	6	31	11	−15	11	−23	16	−24	19	−12	10	−33	13	27	9	10
	II	3.1	11	−11	9	4	1	9	15	−37	5	−29	4	7	5	−22	14	−10	11	30	10	−21	18	18	25	39	22	17
	III	3.3	10	18	8	17	5	14	9	7	4	21	7	9	3	−30	15	−8	31	19	13	−53	23	9	18	19	12	−6
	M_1	3.2	25	6	21	8	14	18	33	−22	19	−10	17	15	19	−21	40	−14	58	22	42	−28	51	3	56	29	43	8
	V	5.5	9	31	7	−8	2	10	8	−1	10	4	7	22	10	2	21	−0	7	−9	25	−1	18	−1	19	−17	24	−8
	VI	7.3	5	−3	2	27	5	−11	3	−22	7	−20	2	37	7	−4	22	−5	19	−7	17	22	13	19	26	−9	20	2
	VII	7.8	6	−3	6	−24	8	−1	7	−12	15	−9	10	19	8	6	22	2	17	−5	29	−6	12	−8	19	0	12	15
	M_2	6.8	20	10	15	−12	15	2	18	−10	32	−6	19	22	25	1	65	−0	43	−3	62	3	43	2	64	−8	56	−1
40° N. 68°–69° W.	I	1.9	5	2	8	−15	5	13	8	−37	6	−26	7	36	13	13	6	−24	15	−4	25	−16	9	−26	20	41	12	28
	II	1.9	10	−8	15	18	2	11	12	−48	6	−13	8	19	10	−24	11	−19	13	23	20	−20	19	34	14	28	27	9
	III	2.6	7	10	6	10	7	33	8	−12	6	45	7	10	6	−30	16	−18	22	−12	19	−30	20	9	22	19	10	−15
	M_1	2.3	22	−2	29	5	14	22	28	−36	18	0	22	20	29	−11	33	−19	50	−1	64	−23	48	12	56	28	49	7
	V	4.5	10	10	7	−17	4	−8	4	16	10	32	6	31	7	−12	12	0	12	−22	20	−1	18	−4	15	−18	22	2
	VI	6.1	5	−13	4	−30	3	−8	11	−17	7	−17	5	31	11	−12	22	−3	9	−12	18	2	14	19	32	−6	21	21
	VII	6.3	5	−19	3	−7	5	8	6	−7	10	−5	8	28	8	−7	20	9	16	−8	18	−26	12	−20	19	14	10	13
	M_2	5.7	20	−6	14	−21	12	1	11	−6	27	5	19	30	26	−13	54	4	37	−14	56	−8	44	−5	66	−1	53	10

TABLE 7L.—Deviations of the air temperatures from the eleven-year means (1900 to 1910) for both decade groups for the 10° longitude fields of the northern shipping route Channel to New York. Deviations are in tenths of a degree Centigrade.

W.Lg.	Mittel 1900—10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
						I—III Dekade. 3. Februar—4. März.								
10—19°	9.3	9	12	−6	−1	−8	13	−13	4	−6	0	6	6	3
20—29°	10.5	−3	−2	−16	5	−3	4	−28	7	1	9	12	11	−8
30—39°	11.3	2	−29	−3	18	3	−9	−32	16	−4	1	25	3	−17
40—49°	10.1	22	−24	−5	12	1	−31	−28	8	21	2	27	−3	−3
50—59°	8.9	32	3	−11	−0	12	−16	−19	−6	11	4	6	9	9
60—69°	5.3	10	27	14	−24	−4	9	−17	−6	18	−23	−3	22	14
10—69°	9.2	12	−4	−4	2	0	−5	−23	4	7	−1	12	8	−1
20—59°	10.2	13	−13	−7	9	3	−13	−27	6	7	4	18	5	−5
						V—VII Dekade. 15. März—13. April.								
10—19°	10.1	11	11	−5	−3	2	−5	−4	1	−2	2	3	9	2
20—29°	11.0	8	15	5	−4	6	−12	−9	−11	−2	7	6	6	8
30—39°	11.6	1	8	16	−4	8	−17	−9	−14	−2	4	8	6	4
40—49°	10.3	−12	−6	12	6	6	−20	6	−13	−6	−11	16	5	−1
50—59°	10.1	−4	−14	0	3	25	−2	3	−11	−21	−4	13	−7	2
60—69°	8.0	−1	−29	−11	−3	7	14	14	−7	−14	6	−6	−6	7
10—69°	10.2	0	−3	3	−1	9	−7	0	−9	−8	1	7	2	4
20—59°	10.7	−2	1	8	0	11	−13	−2	−12	−8	−1	11	3	3
						Mean value for both decade groups together.								
10—69°	9.7	6	−3	−0	0	5	−6	−11	−3	−0	−0	9	5	2
20—59°	10.5	6	−6	1	4	7	−13	−14	−3	−0	1	14	4	−1

TABLE 8L.—Deviations of the air temperatures from the eleven-year means (1900 to 1910) for each decade (I-II) and for each 10° longitude field of the southern region Portugal to 40° west longitude. M gives the mean values of the whole decade group (February 3 to March 4). The first column for each year gives the number of observations, the second column the deviations in tenths of a degree Centigrade.

Feld	Dekade	Mittel 1900—10	1898		1899		1900		1901		1902		1903		1904		1905		1906		1907		1908		1909		1910	
10—19°	I	13.8	12	2	11	23	18	5	51	11	24	8	16	11	12	3	35	−0	11	−18	28	−5	88	−2	16	−15	26	3
W.	II	14.1	17	1	5	−10	19	14	9	−10	16	−10	40	15	11	3	23	−3	37	−5	10	7	36	−8	10	−4	23	2
37 u. 38° N.	III	13.3	25	11	11	14	24	3	15	−5	46	6	19	17	48	−16	19	−5	23	8	7	−5	35	−6	17	−7	14	11
	M	13.8	54	5	27	12	61	7	75	5	86	2	75	15	71	−12	77	−2	71	−2	45	−2	109	−5	43	−10	63	5
10—19°	I	12.8	7	−2			11	0	36	−2	12	3	19	14	12	0	29	−0	14	−25	20	2	40	−1	33	−2	25	10
W.	II	13.2	13	0	4	−3	29	14	17	9	21	0	23	3	10	−1	20	−5	40	−5	13	−16	22	−4	15	1	22	4
39 u. 40° N.	III	12.6	17	8	12	11	23	−4	15	2	33	4	23	14	51	−18	29	1	19	2	9	1	50	−2	16	−6	17	6
	M	12.8	37	3	16	7	63	6	68	2	66	3	65	11	73	−13	78	−1	73	−6	42	−3	112	−3	64	−2	64	8
10—19°	I	12.2	8	−4	10	2	20	4	33	−4	3	3	21	8	14	−11	20	0	14	−8	20	−2	27	−2	18	2	29	10
W.	II	12.4	18	1	4	−3	16	9	13	−1	19	1	21	8	25	−4	19	2	35	−1	14	−14	36	−1	11	−0	15	2
41 u. 42° N.	III	12.0	24	8	34	16	18	−4	8	2	21	0	13	13	22	−15	21	−5	23	3	6	−5	21	−8	20	−1	10	11
	M	12.2	48	4	48	10	54	2	54	−3	43	6	55	9	61	−10	60	−2	72	−1	40	−7	84	−3	49	−0	54	8
10—19°	I	11.1	2	18	13	6	14	−4	19	2	5	2	13	14	8	−15	15	8	16	−14	19	−11	8	4	16	−1	23	16
W	II	11.4	27	10	6	6	22	6	4	−6	6	−2	16	7	33	−3	14	3	18	−8	2	−1	30	5	3	−9	0	[9]
43 u. 44° N.	III	11.2	36	8	35	9	9	0	5	11	21	4	6	−5	21	−10	12	−13	11	9	1	9	22	1	11	7	5	−13
	M	11.3	65	9	54	7	45	2	28	1	32	2	35	7	62	−7	41	−0	45	−7	22	−11	60	3	30	−0	28	10
20—29°	I	14.9	2	0	28	−7	1	−19	30	17	17	4	5	−9	9	6	14	4	0	[11]	2	−6	15	−7	8	−10	13	9
W.	II	14.5	1	−10	4	−10	2	−9	19	11	8	−1	19	−2	15	−7	15	−1	15	5	0	[−2]	33	−0	10	−6	0	[11]
37 u. 38° N.	III	14.7	8	8	18	−4	6	−5	1	−18	2	8	2	−0	10	−14	9	9	10	28	0	[−4]	7	−1	12	3	2	−5
	M	14.8	11	4	50	−6	9	−9	50	13	27	2	26	−6	34	−7	38	2	25	12	2	−6	55	−4	30	−5	15	8
20—29°	I	14.1	1	−2	25	−17	10	−23	9	22	18	14	1	−14	6	−11	16	3	2	−12	5	22	5	−6	28	−3	9	7
W.	II	14.2	4	11	2	−15	9	−10	15	3	11	7	23	1	12	3	26	−2	10	−8	2	14	41	6	9	−2	1	−13
39 u. 40° N.	III	14.3	8	−1	12	−10	10	3	5	29	4	−5	1	1	13	−7	3	13	7	11	1	−31	25	−2	4	−18	2	6
	M	14.4	13	1	39	−17	29	−12	29	11	33	7	25	−2	31	−6	45	−1	19	−3	8	11	71	0	41	−7	12	3
20—29°	I	13.8	6	−5	14	−14	10	−11	8	10	16	10	0	[6]	0	[−21]	8	−4	5	5	10	8	0	[1]	5	−12	11	9
W.	II	13.1	20	23	16	−12	14	−11	0	[14]	6	7	25	10	9	7	17	8	17	−19	20	1	59	10	18	−24	7	−4
41 u. 42° N.	III	13.8	3	−2	9	−2	13	−9	12	6	3	−5	1	35	23	−31	8	9	1	11	51	−18	41	5	15	3	6	6
	M	13.3	29	15	39	−8	47	−8	20	13	25	11	26	10	32	−17	33	7	23	−13	81	−6	100	5	38	−10	24	8

TABLE 7L.—Deviations of the air temperatures from the eleven-year means (1900 to 1910) for both decade groups for the 10° longitude fields of the northern shipping route Channel to New York. Deviations are in tenths of a degree Centigrade.

I—III Dekade. 3. Februar—4. März.

10–19°	9.3	9	12	−6	−1	−8	13	−13	4	−6	0	6	8	3
20–29°	10.5	−3	−8	−16	5	−3	4	−28	7	1	0	10	11	−8
30–39°	11.3	2	−29	−3	18	8	−9	−30	16	−4	1	25	3	17
40–49°	10.1	22	−24	−5	10	1	−31	−28	8	21	8	27	3	−3
50–59°	8.9	32	3	−11	−0	12	−16	−19	−6	11	4	6	0	9
60–69°	3.3	10	27	14	−24	−4	9	−17	−6	16	−23	−3	22	14
10–69°	9.2	12	−4	−4	8	0	−5	−23	4	7	−1	10	8	−1
20–59°	10.2	15	−13	−7	9	3	−18	−27	6	7	4	10	5	−5

V—VII Dekade. 15. März—13. April.

10–19°	10.1	11	11	−5	−3	2	−5	−4	1	−2	2	3	9	2
20–29°	11.0	8	15	5	−4	6	−10	−9	−11	−8	7	6	6	8
30–39°	11.6	1	8	16	−4	8	−17	−9	−14	−8	4	8	6	4
40–49°	10.5	−12	−6	12	6	6	−20	6	−13	−6	−11	16	5	−1
50–59°	10.1	−4	−14	0	3	25	−8	3	−11	−21	−4	13	−7	2
60–69°	8.0	−1	−29	−11	−3	7	14	14	−7	−14	6	−6	−6	7
10–69°	10.2	0	−3	3	−1	9	−7	0	−9	−8	1	7	2	4
20–59°	10.7	−2	1	8	0	11	−13	−2	−12	−8	−1	11	2	3

Mean value for both decade groups together.

10–69°	9.7	6	−3	−0	0	5	−6	−11	−3	−0	−0	9	3	0
20–59°	10.5	6	−6	1	4	7	−13	−14	−5	−0	1	14	4	−1

TABLE 9WL.—Deviations of the difference: Surface temperatures minus air temperature, for both decade groups (M_1: I-III decades February 3 to March 4, and M_2: V-VII decades March 15 to April 13) for the 2° longitude fields of the northern shipping route Channel to New York. Deviations are in tenths of a degree Centigrade.

Br. u. Lg.	Dekade	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
49° N. 10°–11° W.	M_1	1.2	−6	−10	5	1	1	−13	3	2	4	1	−3	4	−5
	M_2	0.4	−3	−3	3	−2	−2	−2	−3	−2	7	−1	1	−2	3
49° N. 12°–13° W.	M_1	1.3	−2	−1	6	−2	2	−13	5	−0	1	3	−0	4	−5
	M_2	0.5	−11	−6	4	−3	−7	3	1	−1	4	1	−2	−1	−1
49° N. 14°–15° W.	M_1	1.4	−4	−16	1	−4	4	−9	4	1	6	6	−5	−0	−3
	M_2	0.7	−1	−8	2	1	−7	8	−1	−2	4	7	−4	−6	−1
49° N. 16°–17° W.	M_1	1.4	−5	−9	8	−1	7	−10	4	0	2	2	−4	−7	−2
	M_2	0.8	−6	−10	0	2	−4	7	−2	−1	3	2	−1	−5	−2
49° N. 18°–19° W.	M_1	1.4	2	−12	9	−0	11	−13	12	−5	−3	2	−3	−6	−2
	M_2	0.6	−8	−9	1	4	−1	4	−4	2	−1	2	−0	−3	−4
48° N. 20°–21° W.	M_1	1.4	−9	−7	15	−2	5	−17	18	−6	−3	1	−5	−8	1
	M_2	0.6	−5	−16	0	2	−8	3	−1	0	4	2	2	−1	−4
48° N 22°–23° W.	M_1	1.1	2	−7	8	−5	6	−10	20	−8	−4	−2	−5	−4	6
	M_2	0.7	−2	−9	−6	7	−5	−0	−1	0	2	3	3	3	−6

Feld	Dekade	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
48° N. 24°–25° W.	M_1	1.2	−2	4	5	−7	−2	−4	19	−7	−1	−1	−10	−2	8
	M_2	0.7	−2	−10	−9	2	−5	9	−1	7	0	3	−1	−2	−3
47° N. 26°–27° W.	M_1	1.2	13	−8	10	−2	2	−7	11	−7	−0	−1	−6	−8	8
	M_2	0.8	2	−11	3	−2	−1	9	−2	4	1	−1	−6	−4	−2
47° N. 28°–29° W.	M_1	1.1	12	1	1	−6	−0	4	9	−7	2	−0	−6	−7	11
	M_2	0.6	2	−10	−5	7	−8	−2	−3	13	4	1	−5	2	−2
47° N. 30°–31° W.	M_1	1.3	0	9	3	−5	7	3	12	−6	−2	−8	−15	−4	10
	M_2	0.7	9	−17	−7	9	−3	−10	−0	8	2	9	−4	−2	−2
46° N. 30°–31° W.	M_1	1.4	−1	16	14	−10	−1	−11	15	−16	4	4	−11	−5	17
	M_2	0.8	0	−1	−12	6	1	4	−5	7	10	−0	−8	−0	−1
46° N. 32°–33° W.	M_1	1.3	6	19	6	−16	9	−7	10	−10	5	3	−13	1	12
	M_2	1.1	−5	−15	−13	9	−8	−2	1	9	6	1	0	1	−3
45° N. 34°–35° W.	M_1	1.8	−9	18	7	−20	−1	−1	17	−12	5	1	−18	5	18
	M_2	1.3	10	1	−7	2	−8	2	2	6	8	−1	−2	1	−2
45° N. 36°–37° W.	M_1	1.9	2	28	−4	−14	−4	4	12	−15	−3	14	−14	5	20
	M_2	1.9	12	−10	−12	9	−2	4	6	3	−5	1	5	−3	−6
44° N. 36°–37° W.	M_1	2.0	7	18	1	−18	−14	1	27	−20	4	−2	−11	10	21
	M_2	1.4	−5	−0	−9	−6	−6	15	−6	−3	12	5	−5	−2	5

TABLE 9WL.—Deviations of the difference: Surface temperatures minus air temperature, for both decade groups (M_1: I-III decades February 3 to March 4, and M_2: V-VII decades March 15 to April 13) for the 2° longitude fields of the northern shipping route Channel to New York. Deviations are in tenths of a degree Centigrade.

Br. u. Lg.	Dekade	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
49° N. 10°–11° W.	M_1	1.2	−6	−10	5	1	1	−13	3	2	4	1	−3	4	−5
	M_2	0.4	−3	−3	3	−2	−2	−2	−3	−2	7	−1	1	−2	3
49° N. 12°–13° W.	M_1	1.3	−2	−1	6	−2	2	−13	5	−0	1	3	−0	4	−5
	M_2	0.5	−11	−6	4	−3	−7	3	1	−1	4	1	−2	−1	−1
49° N. 14°–15° W.	M_1	1.4	−4	−16	1	−4	4	−9	4	1	6	6	−5	−0	−3
	M_2	0.7	−1	−8	2	1	−7	8	−1	−2	4	7	−4	−6	−1
49° N. 16°–17° W.	M_1	1.4	−5	−9	8	−1	7	−10	4	0	2	2	−4	−7	−2
	M_2	0.8	−6	−10	0	2	−4	7	−2	−1	3	2	−1	−5	−2
49° N. 18°–19° W.	M_1	1.4	2	−12	9	−0	11	−13	12	−5	−3	2	−3	−6	−2
	M_2	0.6	−8	−9	1	4	−1	4	−4	2	−1	2	−0	−3	−4
48° N. 20°–21° W.	M_1	1.4	−9	−7	15	−2	5	−17	18	−6	−3	1	−5	−8	1
	M_2	0.6	−5	−16	0	2	−8	3	−1	0	4	2	2	−1	−4
48° N 22°–23° W.	M_1	1.1	2	−7	8	−5	6	−10	20	−8	−4	−2	−5	−4	6
	M_2	0.7	−2	−9	−6	7	−5	−0	−1	0	2	3	3	3	−6

Feld	Dekade	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
48° N. 24°–25° W.	M_1	1.2	−2	4	5	−7	−2	−4	19	−7	−1	−1	−10	−2	8
	M_2	0.7	−2	−10	−9	2	−5	9	−1	7	0	8	−1	−2	−3
47° N. 26°–27° W.	M_1	1.2	13	−8	10	−2	2	−7	11	−7	−0	−1	−6	−8	8
	M_2	0.8	2	−11	3	−2	−1	9	−2	4	1	−1	−6	−4	−2
47° N. 28°–29° W.	M_1	1.1	12	1	1	−6	−0	4	9	−7	2	−0	−6	−7	11
	M_2	0.6	2	−10	−5	7	−8	−2	−3	13	4	1	−5	2	−2
47° N 30°–31° W.	M_1	1.3	0	9	3	−5	7	3	12	−6	−2	−8	−15	−4	10
	M_2	0.7	9	−17	−7	9	−3	−10	−0	8	2	9	−4	−2	−2
46° N. 30°–31° W.	M_1	1.4	−1	16	14	−10	−1	−11	15	−16	4	4	−11	−5	17
	M_2	0.8	0	−1	−12	6	1	4	−5	7	10	−0	−8	−0	−1
46° N. 32°–33° W.	M_1	1.3	6	19	6	−16	9	−7	10	−10	5	3	−13	1	12
	M_2	1.1	−5	−15	−13	9	−8	−2	1	9	6	1	0	1	−3
45° N. 34°–35° W.	M_1	1.8	−9	18	7	−20	−1	−1	17	−12	5	1	−18	5	18
	M_2	1.3	10	1	−7	2	−8	2	2	6	8	−1	−2	1	−2
45° N. 36°–37° W.	M_1	1.9	2	28	−4	−14	−4	4	12	−15	−3	14	−14	5	20
	M_2	1.9	12	−10	−12	9	−2	4	6	3	−5	1	5	−3	−6
44° N. 36°–37° W.	M_1	2.0	7	18	1	−18	−14	1	27	−20	4	−2	−11	10	21
	M_2	1.4	−5	−0	−9	−6	−6	15	−6	−3	12	5	−5	−2	5

TABLE 10WL.—Deviations of the difference: Surface temperature minus air temperature for the 10° longitude fields of the northern route Channel to New York. Deviations in tenths of a degree Centigrade.

W.Lg.	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
I—III Dekade. 3. Februar—4. März.														
10–19°	1.3	−3	−10	6	−1	5	−12	6	−0	2	3	−3	−1	−4
20–29	1.2	3	−3	8	−5	2	−7	15	−7	−1	−1	−6	−6	7
30–39	1.7	−3	21	4	−14	−1	0	15	−14	2	3	−14	3	16
40–49	2.8	−10	8	5	−8	−1	21	11	−8	−12	3	−14	−2	6
50–59	3.9	−20	−19	11	1	−9	−0	1	3	−0	1	−5	−7	3
60–69	4.7	−26	−32	−8	15	−6	−5	20	−5	−7	26	5	−25	−9
10–69	2.6	−10	−6	4	−2	−2	−0	11	−5	−3	6	−6	−6	3
20–59	2.4	−7	2	7	−6	−2	4	11	−6	−3	2	−10	−3	8
V—VII Dekade. 15. März—13. April.														
10–19	0.6	−6	−7	2	1	−4	4	−2	−1	3	2	−1	−3	−1
20–29	0.7	−1	−11	−3	3	−5	4	−2	5	2	2	−2	0	−4
30–39	1.3	5	−7	−11	4	−3	4	−2	5	4	2	−2	−1	−1
40–49	2.3	16	3	−6	−9	−6	5	−8	13	5	13	−5	2	−3
50–59	3.0	13	−6	1	1	−21	−19	−17	9	22	12	−8	11	7
60–69	2.6	6	4	1	−6	−10	3	−13	−8	12	6	−9	9	5
10–69	1.8	6	1	−1	−1	−8	0	−7	4	8	6	−4	3	1
20–59	1.8	8	−5	−5	−0	−9	−2	−7	8	8	7	−4	3	0
Mean value for both decade groups together.														
10–69	2.2	−2	−3	2	−1	−5	0	2	−1	3	6	−5	−2	2
20–59	2.1	1	−2	1	−3	−5	1	2	1	3	5	−7	0	4

Feld	Dekade	Mittel 1900-10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
40° N. 64°–65° W.	M_1	5.4	−33	−56	−35	6	−10	4	16	8	−1	58	20	−40	−27
	M_2	2.4	35	23	20	−9	6	−9	−12	−16	4	3	−4	8	10
40° N. 66°–67° W.	M_1	3.5	−31	−34	−2	5	−6	−12	8	14	9	18	−8	−20	−6
	M_2	0.4	−8	16	20	15	−10	−3	−21	−4	11	−3	−0	−2	−1
40° N. 68°–69° W	M_1	2.5	7	2	−9	20	5	−19	5	−2	11	20	−15	−16	−0
	M_2	0.3	3	14	8	−3	−6	−3	−1	−10	8	5	5	2	−4

TABLE 10WL.—Deviations of the difference: Surface temperature minus air temperature for the 10° longitude fields of the northern route Channel to New York. Deviations in tenths of a degree Centigrade.

W.Lg.	Mittel 1900–10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
						I—III Dekade. 3. Februar—4. März.								
10–19°	1.3	−3	−10	6	−1	5	−12	6	−0	2	3	−3	−1	−4
20–29	1.2	3	−3	8	−5	2	−7	15	−7	−1	−1	−6	−6	7
30–39	1.7	−3	21	4	−14	−1	0	15	−14	2	3	−14	3	16
40–49	2.8	−10	8	5	−8	−1	21	11	−8	−12	3	−14	−2	6
50–59	3.9	−20	−19	11	1	−9	−0	1	3	−0	1	−5	−7	3
60–69	4.7	−26	−32	−8	15	−6	−5	20	−5	−7	26	5	−25	−9
10–69	2.6	−10	−6	4	−2	−2	−0	11	−5	−3	6	−6	−6	3
20–59	2.4	−7	2	7	−6	−2	4	11	−6	−3	2	−10	−3	8
						V—VII Dekade. 15. März—13. April.								
10–19	0.6	−6	−7	2	1	−4	4	−2	−1	3	2	−1	−3	−1
20–29	0.7	−1	−11	−3	3	−5	4	−2	5	2	2	−2	0	−4
30–39	1.3	5	−7	−11	4	−3	4	−2	5	4	2	−2	−1	−1
40–49	2.3	16	3	−6	−9	−6	5	−8	13	5	13	−5	2	−3
50–59	3.0	13	−6	1	1	−21	−19	−17	9	22	12	−8	11	7
60–69	2.6	6	4	1	−6	−10	3	−13	−8	12	6	−9	9	5
10–69	1.8	6	1	−1	−1	−8	0	−7	4	8	6	−4	3	1
20–59	1.8	8	−5	−5	−0	−9	−2	−7	8	8	7	−4	3	0
						Mean value for both decade groups together.								
10–69	2.2	−2	−3	2	−1	−5	0	2	−1	3	6	−5	−2	2
20–59	2.1	1	−2	1	−3	−5	1	2	1	3	5	−7	0	4

Mittel für Januar und Februar.

10–19°	S 73° W 123	+1° 135	+29° 176	−44° 106	+27° 69	+32° 80	+20° 197	−17° 196	+8° 118	−20° 179	+1° 116	−11° 136	+14° 100	−20° 270
		+2	+85	−74	+31	+42	+67	−57	+16	−61	+2	−26	+24	−92
20–29	S 66 W 142	+5 146	+1 168	−35 114	+40 108	+7 80	+6 209	−17 212	+9 142	−155 169	+9 139	+5 160	+11 112	−21 250
		+13	+3	−64	+69	+10	+22	−62	+22	−45	+22	+14	+21	−90
30–39	S 67 W 131	+28 109	−31 197	−12 97	+22 119	+7 98	−9 186	−11 175	+10 138	−10 121	+11 137	+16 141	+9 84	−18 171
		+51	−103	−20	+45	+12	−29	−33	+24	−21	+26	+39	+13	−53
40–49	S 76 W 114	+30 65	−30 202	+2 96	+15 110	+2 82	−14 172	−6 150	+15 118	+6 58	+11 104	+21 105	+22 72	+5 127
		+33	−101	+3	+28	+3	−41	−16	+31	+6	+20	+38	+27	+11
50–59	N 89 W 80	+20 16	−15 142	+12 85	−3 99	+2 74	−13 158	−1 92	+12 100	+41 32	+6 79	+15 87	+3 71	+22 97
		+6	−35	+18	−4	+2	−34	−1	+22	+21	+9	+23	+4	+36
60–69	N 54 W 58	−30 38	+8 80	+48 87	−16 97	−32 63	+11 91	−25 49	−11 65	−78 15	+12 47	+30 60	+4 50	+47 69
		−19	+11	+65	−26	−32	+17	−21	−12	−15	+10	+30	+3	+50
10–69		+14	−23	−12	+24	+17	+0	−32	+17	−19	+15	+20	+15	−23
20–59		+26	−59	−16	+35	+7	−21	−28	+25	−10	+19	+29	+5	−8

Mittel für Februar und März.

10–69°		−8	−1	−7	+27	+2	−9	−25	+4	−8	+20	+11	+6	−10
20–59		+15	−34	−2	+35	−2	−38	−26	+0	+12	+24	+27	+6	−17

Mittel für Januar, Februar und März.

10–69°		+3	−10	−4	+19	+4	−9	−24	+6	−10	+20	+11	+6	−12
20–59		+20	−38	+2	+25	+5	−33	−20	+5	+2	+24	+21	+11	−14

TABLE 12D.—Directions of the isobars and pressure gradients for the 10° longitude fields of the northern shipping route Channel to New York. The average directions of the isobars and the mean relative intensity of the pressure gradients in the second column are computed for the years 1898 to 1908. The first column for each year gives the deviations of the isobars from this mean direction. In the second column for each year are given the relative numbers of pressure gradients (these are the numbers without signs) and the resultant value of the deviations of directions and of pressure gradients (these are the numbers with signs). For further explanation see the text.

Feld	Dekade	Mittel 1900—10	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
41° N. 44°—45° W.	M_1	3.6	−3	−1	11	0	−16	6	14	−17	−16	8	−23	13	−11
	M_2	2.6		−8	−13	2	−32	12	−19	−0	24	13	3	9	1
41° N. 46°—47° W.	M_1	2.8	−14	2	23	−1	−11	1	30	−14	−33	7	−7	3	2
	M_2	2.5	7	14	13	−8	−14	−4	−15	19	6	4	−17	14	1
41° N. 48°—49° W.	M_1	1.6	−14	7	−2	−12	3	27	2	−3	4	−14	−11	−11	18
	M_2	1.0	16	−9	32	−17	−10	−20	−9	18	10	0	−0	7	−10
41° N 50°—51° W.	M_1	1.3	−20	5	−24	−13	35	6	−10	11	10	1	−25	−20	31
	M_2	1.1	1	−3	−6	−0	−3	−17	−4	10	29	−5	−17	−8	22
41° N. 52°—53° W.	M_1	3.0	−13	−53	29	−5	−5	5	−10	−13	−5	2	−45	22	24
	M_2	2.0	18	−14	−5	18	−17	−37	−42	15	16	12	1	16	24
41° N 54°—55° W.	M_1	3.3	−13	−13	20	−9	−24	−2	34	−5	18	−28	−12	1	7
	M_2	2.5	25	−26	−2	23	−27	−23	−30	10	16	5	14	12	2
41° N. 56°—57° W	M_1	4.4	−10	−11	18	−7	−13	10	5	−0	10	10	−14	−22	3
	M_2	3.8	16	−38	0	−2	−42	−40	−25	31	41	27	15	5	−8
41° N. 58°—59° W.	M_1	5.4	−19	−53	6	4	−16	−1	16	4	−23	23	16	−20	−10
	M_2	4.1	1	−19	0	−12	−11	−11	−22	7	33	17	1	12	−13
41° N. 60°—61° W.	M_1	4.8	−31	−43	5	28	−6	8	20	−24	−33	18	13	−13	−14
	M_2	4.2	−5	−35	−15	−13	−12	7	−5	−1	33	17	−7	1	−6

W·Lg.	Mittl. Isobaren-richtung	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	S 79°W 106	−18° 138	+49° 172	−63° 69	+99° 50	+79° 54	+28° 227	−13° 220	+4° 149	−38° 169	−11° 128	−24° 154	+38° 70	−12° 286
		−43	+130	−61	+50	+53	+107	−49	+10	−104	−23	−63	+43	−59
20–29	S 66 W 122	−18 105	+6 162	−60 77	+82 155	+11 60	+12 240	−29 200	+11 182	−32 159	−6 125	+16 162	+24 107	−24 270
		−32	+17	−67	+153	+21	+50	−97	+35	−84	−13	+45	+43	−110
30–39	S 59 W 112	+65 59	−46 190	−43 51	+57 167	−6 83	−6 206	−21 150	+14 143	−16 117	−3 151	+31 139	+1 100	−28 217
		+53	−136	−35	+140	−9	−21	−54	+35	−32	−8	+78	+2	−102
40–49	S 73 W 107	+83 50	−37 193	−37 60	+18 138	−22 78	−14 176	−10 167	+21 122	+39 80	+15 156	+43 79	−9 90	+2 163
		+50	−116	−36	+56	−29	−42	−29	+44	+50	+40	+54	−14	+6
50–59	N 88 W 81	+152 77	−18 166	−13 67	−15 150	+2 91	−20 173	−9 86	+12 114	+87 56	+22 100	+25 54	+2 100	+19 100
		+36	−51	−15	−39	+3	−59	−13	+24	+56	+37	+23	+3	+33
60–69	N 41 W 66	−91 55	+19 83	+52 85	−7 170	−21 71	+17 107	−21 60	+4 88	−101 55	+19 61	+34 50	+45 85	+38 55
		−53	+27	+67	−11	−25	+31	−21	+6	−54	+20	+28	+60	+34
10–69		+2	−22	−24	+56	+1	+11	−44	+26	−28	+9	+28	+23	−33
20–59		+27	−72	−38	+78	−6	−18	−48	+35	−3	+14	+50	+9	−43

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W·Lg.	Mittl. Isobaren-richtung	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	N 88°W 93	−84° 83	+72° 55	−105° 80	−6° 57	+4° 148	+8° 286	−13° 80	+17° 174	−10° 50	+20° 154	−12° 174	−35° 114	+29° 65
		−83	+52	−77	−6	+10	+40	−18	+51	−9	+53	−36	−65	+31
20–29	S 74 W 130	+40 40	+54 95	0 0	+9 90	−8 174	−21 250	−4 150	−9 244	+44 56	+10 210	−8 210	−9 63	+2 105
		+26	+77	0	+14	−24	−90	−10	−38	+39	+37	−29	−10	+4
30–39	S 72 W 08	+57 45	+17 60	+112 78	0 7	−8 125	−31 214	−6 150	−18 222	+62 83	+10 190	−2 182	−2 109	−6 110
		+38	+18	+72	0	−17	−110	−16	−68	+73	+33	−6	−4	−12
40–49	S 82 W 86	0 0	−53 70	+112 33	−16 105	+22 63	−19 105	−1 130	−8 167	−5 83	+16 158	+17 146	+16 91	+14 61
		0	−56	+31	−29	+24	−34	−2	−23	−7	+44	+43	+25	+15
50–59	W 65	−90 50	−20 77	+30 67	−10 97	+20 67	+20 59	+6 87	−6 72	0 77	+13 105	+5 111	+3 80	+33 54
		−50	−26	+34	−17	+23	+2	+9	−7	0	+24	+10	+4	+29
60–69	N 83 W 44	−108 42	+37 81	+7 50	+22 71	0 0	+67 25	−5 40	−28 42	−18 63	−3 95	−12 80	−13 82	+11 45
		−40	+48	+6	+27	0	+23	−3	−20	−19	−5	−17	−18	+9
10–69		−18	+19	+11	−2	+3	−28	−7	−18	+13	+31	−6	−11	+13
20–59		+4	+3	+34	−8	+2	−58	−5	−34	+26	+35	+5	+4	+9

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W.-Lg.	Mittl. Isobaren-richtung	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	S 65° W 142	+17° 160	+8° 187	−41° 152	0° 125	+10° 117	+7° 167	−23° 172	+13° 93	−10° 213	+13° 117	+3° 136	−3° 133	−30° 254
		+47	+26	−99	0	+20	+20	−67	+21	−37	+26	+7	−7	−127
20–29	S 66 W 162	+17 200	−4 174	−21 164	−6 146	+4 101	−3 182	−6 227	+5 103	−3 200	+22 162	−6 164	−2 121	−18 230
		+58	−12	−59	−15	+7	−10	−24	+9	−10	+61	−17	−4	−71
30–39	S 73 W 151	+21 182	−19 205	+1 148	−5 133	+16 114	−15 174	−3 200	+4 134	−5 125	+26 125	+1 168	+14 67	−9 125
		+65	−67	+3	−12	+31	−45	−10	+9	−11	+55	+3	+16	−20
40–49	S 79 W 122	+11 110	−24 212	+19 148	+9 84	+22 95	−8 169	−1 133	+9 114	−34 70	−6 56	+11 143	+59 77	+8 91
		+21	−86	+48	+13	+35	−24	−2	+18	−39	−6	+27	+66	+13
50–59	N 89 W 80	−15 100	−9 118	+27 114	+31 63	+1 57	−4 146	+6 100	+13 87	−17 46	−17 67	+11 120	+6 42	+25 95
		−26	−18	+52	+32	+1	−10	+10	+20	−13	−20	+23	+4	+40
60–69	N 71 W 53	−6 80	−7 77	+39 91	−3 29	−46 55	+4 77	−36 40	−31 42	+19 35	+7 34	+19 71	−71 46	+44 90
		−8	−9	+57	−1	−40	+5	−24	−22	+11	+4	+23	−43	+63
10–69		+26	−28	+0	+3	+9	−11	−20	+9	−16	+20	+11	+5	−17
20–59		+30	−46	+11	+5	+10	−22	−7	+14	−18	+23	+9	+21	−9

W.Lg.	Mittl. Isobaren-richtung	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	S 79° W 106	−18° 138 −43	+49° 172 +130	−63° 69 −61	+99° 50 +50	+79° 54 +53	+28° 227 +107	−13° 220 −49	+4° 149 +10	−38° 169 −104	−11° 128 −23	−24° 154 −63	+38° 70 +43	−12° 286 −59
20–29	S 66 W 122	−18 105 −32	+6 162 +17	−60 77 −67	+82 155 +153	+11 60 +21	+12 240 +50	−29 200 −97	+11 182 +35	−32 159 −84	−6 125 −13	+16 162 +45	+24 107 +43	−24 270 −110
30–39	S 59 W 112	+65 59 +53	−46 190 −136	−43 51 −35	+57 167 +140	−6 83 −9	−6 206 −21	−21 150 −54	+14 143 +35	−16 117 −32	−3 151 −8	+31 139 +78	+1 100 +2	−28 217 −102
40–49	S 73 W 107	+83 50 +50	−37 193 −116	−37 60 −36	+18 138 +56	−22 78 −29	−14 176 −42	−10 167 −29	+21 122 +44	+39 80 +50	+15 156 +40	+43 79 +54	−9 90 −14	+2 163 +6
50–59	N 88 W 81	+152 77 +36	−18 166 −51	−13 67 −15	−15 150 −39	+2 91 +3	−20 173 −59	−9 86 −13	+12 114 +24	+87 56 +56	+22 100 +37	+25 54 +23	+2 100 +3	+19 100 +33
60–69	N 41 W 66	−91 55 −53	+19 83 +27	+52 85 +67	−7 170 −21	−21 71 −25	+17 107 +31	−21 60 −21	+4 88 +6	−101 55 −54	+19 61 +20	+34 50 +28	+45 85 +60	+38 55 +34
10–69		+2	−22	−24	+56	+1	+11	−44	+26	−28	+9	+28	+23	−33
20–59		+27	−72	−38	+78	−6	−18	−48	+35	−3	+14	+50	+9	−43

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W.Lg.	Mittl. Isobaren-richtung	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	N 88° W 93	−84° 83 −83	+72° 55 +52	−105° 80 −77	−6° 57 −6	+4° 148 +10	+8° 286 +40	−13° 80 −18	+17° 174 +51	−10° 50 −9	+20° 154 +53	−12° 174 −36	−35° 114 −65	+29° 65 +31
20–29	S 74 W 130	+40 40 +26	+54 95 +77	0 0 0	+9 90 +14	−8 174 −24	−21 250 −90	−4 150 −10	−9 244 −38	+44 56 +39	+10 210 +37	−8 210 −29	−9 63 −10	+2 105 +4
30–39	S 72 W 08	+57 45 +38	+17 60 +18	+112 78 +72	0 7 0	−8 125 −17	−31 214 −110	−6 150 −16	−18 222 −68	+62 83 +73	+10 190 +33	−2 182 −6	−2 109 −4	−6 110 −12
40–49	S 82 W 86	0 0 0	−53 70 −56	+112 33 +31	−16 105 −29	+22 63 +24	−19 105 −34	−1 130 −2	−8 167 −23	−5 83 −7	+16 158 +44	+17 146 +43	+16 91 +25	+14 61 +15
50–59	W 65	−90 50 −50	−20 77 −26	+30 67 +34	−10 97 −17	+20 67 +23	+20 59 +2	+6 87 +9	−6 72 −7	0 77 0	+13 105 +24	+5 111 +10	+3 80 +4	+33 54 +29
60–69	N 83 W 44	−108 42 −40	+37 81 +48	+7 50 +6	+22 71 +27	0 0 0	+67 25 +23	−5 40 −3	−28 42 −20	−18 63 −19	−3 95 −5	−12 80 −17	−13 82 −18	+11 45 +9
10–69		−18	+19	+11	−2	+3	−28	−7	−18	+13	+31	−6	−11	+13
20–59		+4	+3	+34	−8	+2	−58	−5	−34	+26	+35	+5	+4	+9

TABLE 13D.—Isobar directions and air pressure gradients for the 10° longitude fields for the southern region Portugal to 40° west longitude. The numbers have the same significance as for table 12D.

Januar.

W Lg.	N.-Br.	Mittl. Isobarenricht. u. Druckgradient	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	43–44°	S 68° W 82	+24° 80	+5° 171	−38° 87	+2° 65	+25° 80	0° 141	−23° 151	+43° 53	0° 133	−22° 0	−22° 0	0	28° 160
			+32	+15	−53	+2	+34	0	−59	+36	0	0	0	0	−75
	41–42	S 66 W 52	0 0	+3 148	−44 57	−1 44	+55 69	0 119	−25 132	+36 45	+6 80	−174 60	0	−172° 25	−31 80
			0	+8	−40	−1	+56	0	−56	+26	+8	−6	0	−3	−40
	39–40	S 66 W 30	0 0	+6 114	−50 50	−6 42	+67 65	+14 70	−34 95	+36 4	0	−166 69	0	−174 40	0
			0	+12	−38	−4	+60	+17	−53	+23	0	−17	0	−4	0
	37–38	S 82 W 7	−150 27	+30 70	0	+10 30	+102 55	0	−23 83	+57 35	0	−143 64	−118 42	−164 46	0
			−13	+35	0	+5	+54	0	−32	+29	0	−38	−37	−13	0
		Mittel:	+5	+18	−32	+1	+51	+4	−50	+29	+2	−15	−9	−5	28
20–29°	43–44°	S 63° W 121	+20° 142	−10° 200	−17° 71	−5° 110	+3° 59	−5° 150	−7° 158	+14° 44	+5° 143	+30° 120	−15° 133	+10° 80	−11° 130
			+49	−35	−21	−10	+3	−12	−19	+11	+12	+60	−31	+14	−25
	41–42	S 64 W 95	+23 132	−14 182	−15 60	−3 77	+24 36	−9 160	−6 158	+19 36	+12 120	+47 87	−18 70	+30 50	+9 80
			+52	−44	−15	−4	+15	−25	−16	+12	+25	+64	−22	+25	+13
	39–40	S 59 W 74	+25 127	−23 129	0	−10 63	+36 27	−19 177	−5 143	+10 30	+9 110	+82 81	−52 36	+59 42	+2 40
			+54	−50	0	−11	+16	−58	−12	+5	+17	+80	−28	+36	+1
	37–38	S 58 W 51	+24 118	−34 105	0	−20 51	+68 22	−26 114	−2 100	+6 27	+16 80	+89 75	−86 42	+83 34	0
			+48	−59	0	−17	+20	−50	−3	+3	+21	+75	−42	+34	0
		Mittel:	+51	−47	−9	−10	+14	−36	−12	+8	+19	+70	−31	+27	−3

30--39°	43--44°	S 72° W 133	+22° 154	−21° 230	0° 85	−6° 143	+15° 109	−13° 182	0° 156	+30° 75	−1° 124	+37° 103	+1° 156	+20 58	0° 97
			+58	−82	0	−15	+28	−41	0	+4	−2	+62	+2	+20	0
	41—42	S 71 W 115	+20 139	−24 230	+3 61	−4 105	+15 100	−19 174	−1 156	−3 58	+13 102	+56 84	+2 140	+39 45	+1 77
			+47	−93	+3	−7	+26	−57	−3	−3	+23	+70	−5	+28	+1
	39—40	S 70 W 92	+18 122	−25 214	+9 50	−7 69	+18 60	−18 174	−2 129	−12 45	+18 87	+80 77	+1 82	+48 42	+20 63
			+38	−90	+8	−8	+18	−54	−4	−9	+27	+76	+1	+31	+22
	37—38	S 68 W 64	+14 100	−30 137	+68 14	−4 54	+21 32	−17 150	+1 100	+25 45	+13 77	+100 73	+1 59	+58 37	+46 48
			+24	−69	+13	−4	+11	−44	+2	+19	+17	+72	+1	+31	+34
		Mittel:	+42	−83	+6	−8	+21	−49	−1	+3	+16	+70	+2	+28	+14

Februar.

W.-L.	N.-Br.	Mittl. Isobarenricht u. Druck-gradient	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
10–19°	43–44°	N 87° W 82	−40° 21 −13	+35° 148 +85	−9° 114 −88	0 0	+26° 80 +35	+45° 162 +115	+3° 200 +10	−37° 66 −40	−31° 154 −78	−22° 49 −18	−65° 70 −64	−142° 31 −19	+1° 214 +4
	41–42	N 80 W 56	−12 60 −49	+33 143 +78	+4 140 +10	0 0	+10 95 +16	+60 111 +96	+8 190 +26	−60 45 −39	−37 89 −54	−63 43 −40	−126 90 −73	−130 27 −21	+6 168 +18
	39–40	N 80 W 53	−120 85 −73	+28 129 +61	+13 129 +29	0 0	+23 125 +49	+65 87 +71	+4 167 +12	−71 45 −42	−49 80 −60	−86 50 −50	−133 105 −77	−120 20 −17	+1 127 +2
	37–38	N 66 W 38	−96 65 −65	+42 125 +84	+31 114 +59	0 0	+36 133 +78	+86 68 +68	+14 105 +25	−76 52 −50	−56 70 −58	−78 52 −51	−116 100 −90	−96 17 −17	+6 84 +9
		Mittel:	−50	+77	+20	0	+45	+88	+18	−43	−62	−39	−76	−18	+8
20–29°	43–44°	S 63° W 108	+60° 52 +45	−11° 220 −40	−47 60 −44	+66° 125 +114	−3° 88 −5	+10° 197 +34	−26° 200 −87	+21° 140 +50	−38° 125 −76	−23 80 −31	+23° 90 +36	+18 77 +24	−27° 222 −100
	41–42	S 65 W 87	+95 83 +83	−15 200 −52	−34 50 −28	+52 116 +92	−5 100 −9	+12 174 +36	−24 222 −90	+35 88 +51	−41 70 −46	−28 67 −31	0 0	+18 50 +15	−23 200 −78
	39–40	S 65 W 71	+97 63 +63	−20. 170 −58	−15 70 −18	+27 117 +53	−12 115 −24	+10 136 +24	−22 167 −62	+65 70 +63	−45 30 −21	−37 35 −21	0 0	0 0	−27 167 −76
	37–38	S 55 W 49	+89 61 +61	−33 148 −81	−25 110 −46	+5 125 +11	−23 133 −52	0 118 0	−34 133 −74	+83 62 +61	0 0	0 0	+30 77 +39	0 0	−37 120 −72
		Mittel:	+63	−58	−34	+68	−22	+24	−78	+56	−36	−21	+19	+10	−81
30–39°	43–44°	S 59° W 110	+69° 55 +51	−38° 230 −142	−48° 49 −36	+44° 148 +107	−70° 87 −11	−6° 190 −20	−22° 162 −60	+19° 130 +42	−1° 90 −2	−7° 125 −15	+39° 140 +88	−3° 104 −[illegible]	−29° 238 −115
	41–42	S 64 W 108	+88 49 +49	−31 260 −134	−50 60 −46	+28 144 +68	−10 95 −16	−1 171 −3	−19 207 −67	+28 108 +51	+22 56 +21	−2 100 −3	+45 134 +95	+3 93 +5	−21 200 −72
	39–40	S 64 W 100	+94 44 +44	−29 207 −101	−50 68 −52	+12 164 +31	−18 111 −34	−4 162 −11	−16 190 −52	+36 86 +60	+42 50 +33	−5 75 −7	+50 133 +102	−1 76 −1	−16 187 −52
	37–38	S 67 W 87	+97 41 +41	−31 178 −92	−45 95 −67	+4 158 +11	−17 180 −52	−5 136 −12	−14 167 −40	+43 73 +50	+72 40 +38	−20 30 −1	+59 115 +99	0 60 0	−3 116 −6
		Mittel:	+46	−117	−50	+54	−28	−11	−55	+51	+23	−6	+96	−0	−61

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10–19°	43–44°	S 81° W 80	+22° 41 +15	+20° 158 +54	−23° 100 −39	+15° 33 +0	+27° 78 +35	+24° 148 +60	−9° 175 −27	−40° 37 −26	−18° 127 −39	−34° 25 −14	−77° 35 −34	−154° 16 −7	−13° 187 −42
	41–42	S 84 W 52	−141 30 −19	+19 145 +47	−16 98 −27	+17 22 +0	+38 72 +44	+30 111 +55	−7 111 −14	−11 19 −4	−17 67 −20	−124 41 −34	−142 45 −28	−150 26 −13	−11 124 −24
	39–40	S 88 W 40	−132 43 −32	+22 121 +45	−7 87 −13	+16 21 +0	+35 76 +44	+45 77 +54	−10 131 −23	−22 14 −5	−61 40 −35	−125 55 −45	−145 53 −30	−145 30 −17	−11 64 −12
	37–38	N 70 W 22	−105 46 −44	+45 96 +68	+27 57 +26	+38 15 +9	+55 68 +56	+82 34 +84	+8 94 +13	−53 10 −8	−60 35 −30	−100 56 −55	−111 69 −64	−127 36 −24	+2 42 +1
		Mittel:	−20	+54	−13	+2	+48	+51	−12	−10	−31	−37	−39	−15	−19
20–29°	43–44°	S 63° W 114	+30° 93 +47	−11° 210 −38	−23° 63 −25	+33° 96 +52	−1° 73 −1	+3° 172 +9	−18° 177 −55	+19° 92 +30	−14° 125 −30	+9° 90 +14	+1° 105 +2	+14° 78 +19	−18° 177 −55
	41–42	S 65 W 91	+50 89 +68	−15 191 −48	−24 54 −22	+30 87 +44	+2 66 +3	+2 165 +7	−17 188 −55	+19 61 +20	−8 85 −11	+15 61 +16	−18 35 −11	+19 50 +17	−15 135 −34
	39–40	S 62 W 72	+47 80 +58	−22 149 −56	−18 35 −11	+13 87 +20	−6 67 −7	−6 154 −17	−15 152 −39	+48 51 +38	+1 64 +1	+56 34 +28	−52 18 −14	+62 21 +19	−24 101 −41
	37–38	S 57 W 50	+44 76 +53	−34 126 −69	−24 55 −22	−2 86 −2	−13 68 −15	−13 112 −24	−11 113 −21	+72 36 +34	+13 40 +9	+87 38 +38	−176 33 −3	+81 17 +17	−36 60 −35
		Mittel:	+57	−52	−20	+29	−5	−6	−42	+31	−7	+24	−6	+18	−41
30–39°	43–44°	S 66° W 121	+29° 94 +47	−30° 230 −114	−20° 64 −21	+19° 124 +41	+4° 98 +8	−10° 182 −32	−12° 159 −32	+14° 100 +25	−3° 106 −5	+13° 110 +26	+18° 134 +42	+6° 80 +9	−19° 167 −53
	41–42	S 68 W 111	+34 80 +45	−28 245 −113	−24 56 −22	+15 118 +30	+2 97 +4	−10 168 −29	−11 181 −33	+18 79 +25	+16 78 +22	+24 84 +35	+22 124 +47	+15 67 +18	−14 138 −32
	39–40	S 67 W 96	+34 68 +38	−27 210 −95	−25 53 −22	+70 114 +14	−5 83 −7	−11 165 −32	−8 159 −22	+21 59 +21	+26 66 +29	+38 59 +36	+32 96 +51	+17 55 +16	−6 122 −13
	37–38	S 68 W 75	+35 56 +32	−30 158 −79	−36 46 −27	+3 106 +5	−11 103 −20	−11 143 −27	−8 130 −18	+18 49 +15	+34 51 +29	+76 37 +36	+41 77 +50	+22 43 +16	+11 76 +14
		Mittel:	−41	−100	−23	+23	−4	−30	−26	+22	+19	+33	+48	+15	−21

TABLE 14D.—Isobar directions and pressure gradients for the 10° longitude fields of the Danish observational region between 50° and 60° north latitude (see also plate 15). The numbers have the same significance as in table 12D.

Januar.

W.-Lg.	Mittl. Isobarenricht. u. Gradient	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
0–9°	S 69° W 200	+1° 283 +5	+17° 105 +31	−1° 143 −3	+15° 160 +41	−33° 250 −136	+20° 195 +67	+14° 222 +54	+3° 250 +13	0° 228 0	−14° 230 −56	−3° 220 −12	−3° 259 −14	−13° 188 −42
10–19	S 61 W 219	+9 353 +55	+34 154 +86	−18 211 −65	+11 194 +37	−9 182 −29	+12 171 +36	−3 234 −12	−11 253 −48	−8 256 −36	−9 240 −38	+2 227 +7	−9 231 −36	−14 208 −51
20–29	S 67 W 218	+15 285 +73	+14 133 +32	−12 253 −53	+5 170 +15	+3 181 +9	+3 134 +7	−3 250 −13	−6 207 −22	−17 247 −72	+9 235 +57	+3 200 +10	−8 235 −33	−28 244 −114
30–39	S 73 W 169	+11 182 +35	−20 118 −40	−1 247 −4	−1 150 −3	+10 148 +26	−7 121 −15	−4 242 −17	+7 155 +19	−15 182 −47	+13 175 +39	+1 171 +3	+11 193 +37	−26 205 −70
	Mittel:	+42	+27	−31	+23	−32	+24	+3	−9	−39	−4	+2	−11	−69

Februar.

W.-Lg.	Mittl. Isobarenricht. u. Gradient	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
0–9°	S 88° W 124	−18° 254 −78	+72° 115 +111	−164° 70 −19	−74° 136 −131	+73 67 +64	+21° 272 +98	+68° 107 +99	−1° 240 −4	−24° 154 −63	0° 200 0	−19° 230 −75	+35° 111 +64	+43° 200 +136
10–19	S 73 W 124	−17 267 −78	+76 171 +166	−145 108 −62	0 0 0	+96 82 +82	+17 267 +78	+26 34 +15	−5 250 −22	−20 166 −57	−3 214 −11	−23 263 −101	+25 126 +53	−6 230 −24
20–29	S 74 W 126	−18 278 −86	+74 120 +115	−119 118 −103	+90 143 +143	+179 53 +1	+20 251 +86	−25 120 −51	+9 206 +32	−17 245 −71	−5 210 −18	−11 230 −44	+35 134 +77	−30 227 −114
30–39	S 71 W 101	−16 200 −55	−83 72 −71	−139 36 −24	+101 178 +174	−168 75 −16	+5 221 +19	−23 167 −65	+13 157 +35	−21 225 −81	+6 182 +19	+23 141 +55	+32 143 +76	−35 140 −80
	Mittel:	−74	+80	−52	+47	+33	+70	−0	+10	−68	−2	−41	+68	−20

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0–9°	S 72° W 94	−48° 82 −61	−38° 83 −51	−110° 75 −71	−11° 25 −5	−6° 115 −12	+12° 235 +49	+30° 136 +68	+47° 146 +103	−43° 153 −102	−1° 210 −4	+65° 97 +88	+179° 138 +2	+8° 154 +21
10–19	S 71 W 130	−28 144 −68	+19 102 +34	−105 51 −49	+8 43 +6	−8 181 −25	−5 248 −22	+23 160 +63	+37 170 +100	−25 129 −55	+6 251 +26	−7 111 −14	−168 151 −31	+16 174 +48
20–29	S 77 W 145	+14 138 +33	+41 98 +64	−53 27 −22	+22 67 +25	−3 174 −9	−20 250 −86	+12 157 +33	−10 222 −39	+4 127 +9	+1 256 +45	−10 154 −27	−151 96 −46	+5 142 +12
30–39	S 75 W 114	+21 77 +28	+39 61 +38	+75 112 +109	−15 39 −10	−34 140 −78	−32 238 −126	−3 143 −8	−25 186 −79	+42 107 +72	+11 214 +41	+2 150 +5	+160 84 +29	−10 118 −20
	Mittel:	−17	+21	−8	+4	−31	−46	+39	+21	−19	+27	+13	−11	+15

Mittel für Januar und Februar.

0–9°	S 76° W 161	−10° 254 −44	+42° 104 +70	+8° 37 +5	−26° 88 −39	−12° 131 −27	+16° 231 +64	+32° 158 +84	−1° 245 −4	−10° 178 −31	−9° 215 −34	−14° 222 −53	+10° 184 +32	+14° 184 +44
10–19	S 66 W 170	−2 293 −10	+54 161 +130	−41 74 −49	+16 97 +27	+21 98 +35	+12 219 +45	+4 133 +9	−9 251 −39	−13 210 −47	−7 227 −27	−13 232 −52	+4 175 +12	−11 219 −42
20–29	S 71 W 168	−1 280 −5	+43 113 +77	−36 116 −68	+39 113 +71	+3 64 +3	+14 192 +47	−9 183 −29	+3 206 +11	−17 246 −72	+3 222 +12	−4 214 −15	+9 176 +27	−28 235 −111
30–39	S 73 W 135	−2 190 −7	−43 83 −56	−8 108 −15	+57 102 +85	+5 37 +3	+2 170 +6	−12 203 −42	+11 156 +30	−17 203 −59	+19 178 +31	+13 155 +35	+8 156 +22	−25 171 −72
	Mittel:	−16	+55	−32	+36	+4	+41	+6	0	−52	−4	−21	+23	−45

TABLE 15D.—Isobar directions and air pressure gradients for Liepe's Stations in 1° fields I-VII.[1] The isobar directions given here in the first column of each year are not deviations from the mean directions as in the earlier tables 12D to 14D but they are deviations from the direction W computed; + indicates that the direction lies southerly from the direction W—E and — indicates northerly of this direction. The second column for each year gives the relative numbers of air-pressure gradients.
[1] The stations for 1° fields lie between the following degrees of north latitude and west longitude.

Januar.

Station	Mittl. Isobaren-richt. u. Druckgrad.	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
I		+40° 95	+23° 167	−18° 154	+28° 80	+22° 83	+46° 200	+17° 148	+50° 30	0° 154	−28° 90	+20° 32	−8° 50	−4° 200
II		−135 30	+28 143	−22 80	+23 57	+53 28	+42 138	−8 111	+45 40	−15 70	−155 71	0 0	−153 42	0 0
III		−155 40	+45 65	−125 45	0 0	+162 75	0 0	−110 67	+160 30	0 0	−129 67	−123 35		
IV		−157 51	0 0	−145 67	0 0	+158 53	−62 20	−143 74	+180 30	−163 30	−120 40	−45 33		
V		−159 74	−168 44	−162 78	−173 46	+177 42	−139 48	−165 67	−175 45	+180 65	+178 80	−155 34		
VI		−161 69	−152 59	−163 75	−150 42	−175 56	−148 55	−170 63	−177 50	−177 90	−174 59	−168 50		
VII		−163 50	−159 67	−173 57	−156 57	−157 40	−151 63	−170 38	−177 50	−170 40	+180 30	+176 50		

Februar.

Station	Mittl. Isobaren-richt. u. Druckgrad.	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
I		−29° 154	+62° 182	+50° 172	−108° 105	+45° 56	+45° 160	+2° 205	−40° 70	−37° 154	−35° 76	−40° 136	−133° 32	+3° 250
II		−105 78	+53 125	+10 182	−115 30	+22 110	+50 80	−2 174	−85 100	−47 130	−65 45	−118 87	−140 32	−18 160
III		−120 72	+22 110	+12 111	−115 25	+20 133	+71 34	−15 71	−120 59	−70 43	−102 47	−128 80		
IV		−176 68	−7 50	+11 55	−20 48	+1 70	−167 70	−125 48	−178 67	−145 69	−107 57	−130 67		
V		−164 72	−137 91	0 0	−135 50	−90 33	−157 68	−173 59	−177 69	−157 83	−133 61	−168 74		
VI		−156 68	−139 78	−157 47	−148 73	−135 60	−156 69	−175 70	−175 70	−163 74	−163 57	−170 67		
VII		−156 61	−153 71	−158 80	−152 71	−148 50	−153 55	−165 50	−169 50	−161 43	−180 52	−165 48		

März.

I	− 9° 63	− 75° 69	0° 0	−110° 53	0° 0	− 6° 115	+ 10° 230	0° 0	+ 12° 190	0° 0	− 22° 57	− 20° 115	−22° 127	0 0
II	− 56 38	−127 125	+153 95	−110 57	− 23 77	− 55 50	- 5 87	− 60 58	+ 3 150	0 0	−122 59	− 40 103	−23 142	0 0
III	− 84 37	− 95 65	− 25 31	−106 27	− 38 55	−125 38	−112 64	− 70 53	− 7 56	0 0	−131 77	− 84 62		
IV	−123 34	−110 45	− 40 35	−143 20	− 56 35	−146 46	−142 77	− 80 38	−163 34	0 0	−134 69	−143 67		
V	−143 50	−135 49	−122 60	0 0	−142 65	−144 54	−150 94	−115 21	−147 55	−160 20	−143 68	−154 74		
VI	−146 52	−135 43	−130 57	0 0	−140 65	−135 51	−152 69	−155 56	−142 59	−160 50	−162 65	−144 68		
VII	−155 49	−155 37	−155 60	−145 56	−146 62	−157 50	−160 58	−162 53	−147 45	−148 36	−167 50	−164 30		

Resultant von Januar und Februar.

I	+ 13° 95	− 4° 104	+ 42° 165	+ 22° 140	− 60° 37	+ 32° 65	+ 46° 180	+ 8° 175	− 17° 38	− 18° 153	− 31° 83	− 29° 78	− 48° 20	0° 225
II	− 6 49	−120 52	+ 39 131	+ 1 127	− 71 28	+ 28 68	+ 46 108	+ 5 142	− 64 40	− 36 96	−122 42	- 118 44	−147 37	−18 80
III	− 76 15	−139 54	+ 30 86	−110 42	−115 18	+ 52 44	+ 71 17	− 61 47	−145 35	− 70 22	−118 55	−126 57		
IV	−136 25	−168 59	− 7 25	− 93 14	− 20 24	+ 45 15	−151 34	−130 60	+179 49	−152 49	−113 48	−105 39		
V	−160 56	−161.5 73	−146 65	−162 39	−153 45	−143 26	−148 58	−169 63	−176 57	−167 73	−161 65	−164 54		
VI	−162 61	−158.5 69	−145 68	−160 61	−149 57	−153 54	−152 62	−173 66	−176 60	−171 82	−169 58	−169 58		
VII	−163 52	−159 55	−156 69	−165 65	−154 64	−152 45	−152 59	−168 44	−173 50	−165 41	+180 41	−175 49		

The stations or 1° fields lie between the following north latitudes and west longitudes:

Stationen	I	II	III	IV	V	VI	VII
N-Br.	47−48°	42−43°	35−36°	30−31°	23−24°	18−19°	8−9°
W-Lg.	6−7	9−10	13−14	15−16	18−19	21−22	25−26

TABLE 16D.—Isobar directions and pressure gradients at different coast stations. The numbers have the same significance as in table 12D. With respect to the significance of the isobar directions marked + and — for Stad and for Torungen, see the text. For Hamburg the isobar directions measured from the west are indicated by + on the south side and with — on the north side of this direction. This is also the case for Iceland (east and west) for March.

[1] Excepting Stad at 62° 30′ north latitude 5° east longitude.
[2] Torungen at 58° 25′ north latitude 8° 48′ east longitude.
[3] Southerly Shetland Islands at 60° north latitude 1° 20′ west longitude.
[4] East Coast Islands at 65° north latitude 14° west longitude.
[5] At Reykjenes on the West Coast Islands at 64° north latitude 22° 30′ west longitude.
[6] At the West Coast Islands at 54° north latitude 10° west longitude.

Dezember.

Station	Mittl. Isobarenricht. u. Gradient	1894	1895	1896	1897	1898	1899	1900
Stad [1]	S 42° W 221	+18° 154	−15° 168	+118° 214	−12° 210	+13° 240	−15° 220	+ 4° 250
		+48	−43	+188	−43	+ 53	− 57	+17
Torungen [2]	S 10 O	+85 66	−60 78	−30 100	+39 115	+76 154	−60 181	+67 95
		+66	−68	−50	+ 72	+ 149	−157	+88

Januar.

Station	Mittl. Isobarenricht. u. Gradient	1895	1896	1897	1898	1899	1900	1901
Stad [1]	S 56° W 245	−36° 157	+23° 243	−37° 200	+17° 343	−36° 222	−26° 235	+ 2° 278
		− 92	+95	−120	+100	−130	−103	+10
Torungen [2]	S 10 O	−69 173	+25 192	−95 213	+95 154	−10 59	−63 167	+61 79
		−152	+82	−212	+154	− 10	−148	+69
Hamburg					+ 1 184	+ 2 157	+11 77	+24 138

Februar.

Stad [1]	S 49° W 170	−37° 50	+14° 300	+21° 194	−13° 250	−15° 100	−61° 334	+81° 120
		− 30	+72	+ 70	−56	− 26	−290	+119
Torungen [2]	S 10 O	−69 215	+92 77	+47 147	+28 85	+70 60	−79 200	+12 63
		−200	+77	+107	+40	+ 56	−196	+ 13
Shetland [3]	W 106				−16 166	+68 101	−141 115	−75 125
					−46	+ 93	− 72	−121
Thorshavn	N 79 W 71				+ 3 190	+91 77	−141 235	−62 125
					+10	+ 77	−147	−110
Ostküste Islands [4]	N 33 O 42				−48 90	+90 80	−148 250	−64 48
					−67	+ 80	−132	− 43
Reykjanes [5]	S 24 W 59				−19 100	+56 200	+137 250	−3 53
					−32	+166	+170	− 3
Stornoway	S 86 W 125				−18 304	+74 123	+170 60	−84 125
					−94	+118	+ 10	−124
Irland [6]	S 80 W 137				−22 210	+68 158		−85 70
					−79	+146		− 70
Hamburg					− 4 150	+30 78	+ 50 125	−17 90

März.

Stad [1]	S 48° W 130	−26° 117	−22° 192	−39° 182	+12° 175	+87° 100	+92° 100	−26° 50
		−51	−72	−114	+35	+100	+100	−22
Torungen [2]	S 10 O	−12 60	+ 18 66	−75 135	−43 111	+75 118	−38 65	−70 66
		−12	+20	−130	−75	+114	− 40	−62
Shetland [3]	S 51 W 95				−59 62	−116 105	−129 98	+ 1 26
					−53	− 95	− 76	0
Thorshavn	S 59 W 55				−48 83	−111 40	−89 78	0 0
					−63	− 37	− 78	0
Ostküste Islands [4]	S 76 O 46				−98 59	+160 53	−48 61	−149 40
Reykjanes [5]	S 49 O 99				+79 91	+170 102	+ 12 50	+134 50
Stornoway	S 77 W 105				−45 125	−31 83	−107 75	−3 89
					−88	− 43	− 72	− 2
Irland [6]	S 86 W 114				−59 133	+6 121	−109 59	−9 42
					−114	+ 13	− 56	− 7
Hamburg					0 0	−17 160	− 80 42	+110 36

1901	1902	1903	1904	1905	1906	1907	1908	1909
−37° 160	+ 6° 270	−15° 300	+15° 190	+30° 270	+24° 240	−30° 220		
−96	+28	− 78	+49	+135	+97	−110		
− 7 143	+57 75	−43 166	+83 100	+80 165	+60 71	−52 181		
−17	+63	−113	+99	+162	+61	−143		

1902	1903	1904	1905	1906	1907	1908	1909	1910
+44° 214	−10° 263	−16° 308	+ 7° 330	−5° 230	+10° 222	+14 222	+ 8° 254	−15° 250
+148	−46	− 85	+40	−20	+38	+ 54	+ 35	−64
+62 156	+53 86	+48 139	+95 83	+55 92	+68 74	+65 143	+72 113	+48 90
+137	+69	+103	+83	+75	+69	+130	+107	+67
−21 235	+23 162	+37 154	−17 167	+18 200	−25 170	−6 154		

+ 1° 188	+29° 274	−34° 238	+27° 250	− 20° 190	+21° 230	+ 38° 193	− 9° 150	−17° 274
+ 3	+132	−139	+114	− 65	+ 82	+118	− 23	− 80
+ 43 81	+75 210	− 50 170	+75 127	+ 48 140	+96 87	+ 60 182	−40 50	+22 153
+ 55	+202	−130	+122	+104	+ 86	+157	− 32	+ 57
+ 42 80	+14 253	+ 80 137	+ 6 208	− 32 125	0 200	− 17 200	+31 75	+48 200
+ 54	+ 61	+135	+ 22	− 66	0	− 59	+ 39	+149
0	+38 222	+152 64	+14 180	− 44 125	+21 184	− 4 187	+53 129	+57 190
	+136	+ 30	+ 43	− 87	+ 66	− 13	+103	+160
−136 53	+50 60	+171 160	−65 70	−125 125	−29 60	− 70 69		
− 37	+ 46	+ 25	− 63	−102	− 29	− 65		
+100 125	+49 110	+ 89 133	−33 100	+ 24 125	−25 120	−112 62	− 6 174	+96 185
+123	+ 83	+133	− 54	+ 51	+ 51	− 57	+ 60	+162
+76 80	+21 303	+ 78 122	− 4 270	− 25 167	+ 2 180	− 22 260	+33 103	
+ 78	+109	+119	− 19	− 70	+ 6	− 97	+ 56	
+80 115	+20 286	+ 15 143	−10 225	− 29 210	− 3 210	− 24 220	+28 117	
+113	+ 98	+ 37	− 39	−102	− 11	− 90	+ 55	
+130 80	− 2 320	+ 43 117	−17 143	+ 38 143	−18 170	− 20 222	−50 40	+33 167

−10° 170	−10° 300	−18° 240	−35° 170	+82° 190	+12° 240	−52° 220	−58° 143	+12° 261
− 30	− 51	− 74	− 97	+ 19	+50	−173	−121	+54
−66 67	+56 244	−38 154	+ 7 133	+34 130	+75 100	−32 200	−49 238	+88 77
− 61	+202	− 95	+ 15	+ 73	+96	−106	−180	+77
− 7 125	+ 5 265	+16 166	+38 174	−77 158	−22 200	+66 125	105	167
− 15	+ 23	+ 46	+107	−154	−75	+114		
−174 87	+ 9 140	+25 154	+81 120	−63 130	− 4 214	+57 138	−151	+ 1 182
− 9	+ 22	+ 65	+119	−104	−15	+118		+ 3
+180 160	−160 143	+95 100	+146 150	−75 90	+47 100	+133 153	−152 187	+34 145
+162 310	+175 200	+102 125	+150 210	0 0	+59 162	+150 160	−162 181	+51 145
− 7 143	+12 240	+33 166	+48 135	−37 148	+ 4 206	+40 84		
− 17	+ 50	+ 90	+100	− 89	+14	+ 54		
0 154	+12 250	+46 70	+22 190	−16 125	+ 7 182	+ 4 120		
	+ 52	+ 50	+ 71	− 34	+22	+ 8		
+15 118	+38 187	+136 100	+68 95	−25 203	−10 121	+90 150	+77 91	−15 100

Juli.

Station	Mittl. Isobarenricht. u. Gradient	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Stad[1]	N 61° W 27	0° 0	0° 0	+59° 100	−20° 95	+40° 87	−51 56	+111° 77	−61° 71	−146° 59	+34° 55	+29° 53	+74° 84	−71° 83	−83° 13		
		0	0	+86	−32	+56	−43	+75	−62	−33	+31	+26	+81	−78	−13		
Torungen[2]	N 53 W 65	+38 91	−3 32	− 4 160	−22 105	+ 8 56	−17 111	0 0	−20° 74	+ 47 57	+14 100	− 8 91	+41 53	−12 100	+27 15		
		+56	−2	−11	−39	+8	−32		−25	+42	+24	−13	+35	−21	+ 7		

August.

Station	Mittl. Isobarenricht. u. Gradient	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
Stad[1]	N 79° W 42	+44° 83	0° 0	+79° 76	+35° 111	− 4° 50	−19° 32	+31° 95	−74° 46	+14° 66	−59° 49	+46° 40		−4 80			
		+58	0	+74	+64	− 3	−10	+49	−44	+16	−42	+29		− 6			
Torungen[2]	N 82 W 53	−10 98	−9 71	+67 83	+20 77	−48 57	+46 31	+24 67	−34 47	+ 1 36	−19 70	+43 51	−4° 43	+6 106	−32° 50		
		−17	−11	+76	+26	−42	+22	+27	−26	+ 1	−23	+35	−3	+11	−26		

Table 17D.—Deviations of the air-pressure differences over the North Atlantic between the Azores maximum and the Iceland air-pressure minimum in tenths of a millimeter.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Jahres-Mittel
Mittel	24.9	24.1	19.5	15.9	12.4	14.3	15.2	15.1	16.5	18.0	20.5	24.5	18.4
1883												−45	
84	−9	39	45	−79	−4	37	−32	29	35	0	−45	55	5.9
85	31	−41	−15	21	−4	17	−12	−51	15	−80	−45	−85	−20.8
86	−29	−81	−35	−59	−24	−3	8	29	−25	0	−5	−25	−20.8
87	51	−1	−55	−39	−4	−23	8	−51	−25	0	−45	−85	−22.4
88	−89	−101	−55	−39	−24	17	28	−31	−45	−40	35	35	−25.8
89	−29	−41	−55	21	56	37	−32	29	−65	−20	−5	55	−4.1
90	91	−21	25	21	16	17	48	9	15	20	55	−35	21.8
91	−69	19	−15	−39	−4	−43	−32	9	35	60	−25	35	−5.8
92	−29	−141	−95	−39	−44	17	8	−11	35	−60	−25	−45	−35.8
93	−149	19	5	1	−4	−23	8	−51	35	0	−25	15	−14.1
94	11	99	45	41	36	57	8	−11	−25	−60	75	−25	20.9
95	−129	−41	5	−19	36	−43	−12	9	−5	−40	15	−45	−22.4
96	−9	19	45	41	16	−23	28	9	−25	0	−25	75	12.6
97	−89	19	45	101	16	−43	−12	29	15	−20	−45	15	2.6
98	91	19	−75	81	−24	−23	−12	29	15	0	−5	15	9.3
99	−9	39	−75	−39	−64	17	8	9	15	20	75	−85	−7.4
1900	31	−81	−35	−19	16	17	−32	−11	35	0	55	55	2.6
01	31	−21	5	1	−24	−3	8	9	35	20	15	−25	4.3
02	31	−81	−15	−59	16	−23	−12	−31	−65	20	15	15	−15.8
03	11	119	145	−19	−4	−23	−12	29	15	20	35	35	29.3
04	71	19	−15	101	36	17	8	9	35	40	−5	−5	25.9
05	31	79	85	1	36	17	−12	29	−25	−40	35	55	24.3
06	71	19	5	41	−4	−3	28	−11	15	40	−65	15	12.6
07	11	39	85	21	−24	17	−32	9	15	20	35	55	20.9
08	31	59	45	21	16	−3	8	−31	−5	60	−25	35	17.6
09	31	−61	−35	1	−44	−3	48	9	−45	40	−45	−65	−14.1
10	11	119	−15	−59	−4								

TABLE 18L.—Deviations of the air temperatures in the four regions of the United States of America in hundredths of a degree Centigrade. The mean temperatures are computed for all the regions from the time interval 1883 to 1913.

TABLE 18La.—States on the Pacific coast. Mielke's region No. 10.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Jahres-Mittel
Mittel	8.06	9.00	10.70	12.45	14.65	17.10	19.31	19.30	17.59	14.77	11.68	9.00	12.88
1874			−181	−717	63	−115	−109	−158			−35	11	
75		22	−64	99	−4			−80			[illegible]	200	
76	−11			−123	−54	45		−158			65	44	
77	250	267	58	10	−59		−42	−102			110	128	
78	194	178	163	39	57	−4	−176	−130			32	−72	10
79	−156	66	141	[illegible]	−88	7	−114	9			−151	−139	41
80	−117	−239	−220	−45	7	12	119	−113			−273	22	−76
81	71	189	74	232	152	45	−109	−41			−129	11	27
82													
83	−173	−205	219	−12	135	379	369	220			−51	−17	40
84	27	−89	19	110	235	145	164	259			71	178	88
85	33	50	325	232	224	79	197	64			49	133	139
86	22	250	−42	44	202	240	242	243			−140	167	99
87	138	−256	136	−6	12	29	−54	−80			10	[11]	2
88	−211	111	−31	166	23	29	−9	47			−29	77	37
89	27	156	241	194	119	140	69	53			98	−61	109
90	−244	−111	−20	21	185	7	80	109			[illegible]	144	48
91	160	−445	58	27	52	18	108				127	−83	41
92	122	106	91	−72	57	−49	−87				82	−17	25
93	−11	−83	−115	−145	−43	−104	−92				−118	61	−79
94	−117	−189	−142	−6	−26	−160	−20				60	−105	−50
95	−67	122	−59	−23	18	23	−76				−73	−78	−28
96	144	184	3	−206	−104	29	86				−185	128	4
97	5	−28	−259	110	196	1	−42				−95	−11	−13
98	−139	128	−131	61	−105	23	−54				−84	−89	−33
99	100	−56	−82	−39	−226	−82	−87				116	0	−47
1900	149	83	174	−34	63	40	−36				49	[illegible]	23
01	0	61	58	−139	−76	−115	−136				76	22	−23
02	−40	111	−109	−67	−59	−10	−92				−90	−23	−37
03	55	−128	−87	−112	−50	29	−198				27	39	−41
04	44	−45	−109	66	29	34	−114				160	50	17
05	116	133	174	83	−93	−60	8				−90	−72	9
06	105	189	−26	−112	248	−77	57				−79	−5	[illegible]
07	−162	206	−131	44	−4	−77	−31				[illegible]	61	−14
08	89	−45	3	[illegible]	−165	−121	46				−7	−178	−45
09	−11	−17	−115	16	−298	−55	−125				−46	−200	−94
10	−128	−94	125	105	108	−115	−48				−51	−50	−22
11	5	−161	[illegible]	−123	−137	−115	−9				−35	−100	−71
12	133	133	−131	−178	7	−32	−109				10	−61	−41
13	−162	−67	−120	−61	−32	−77	−14				−7	[−5]	−31

TABLE 18Lb.—Interior states. Mielke's region No. 16.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Jahres-Mittel
Mittel	−2.76	−1.63	3.64	9.63	15.05	20.12	22.96	22.07	17.99	11.59	4.88	−0.30	10.27
1883	−274	−137	−42	−207	−144	32	10	−1	−71	−126	68	147	−62
84	−74	74	−3	−57	39	71	−90	−7	29	135	106	−42	15
85	−218	−143	−97	−119	−44	−95	48	−101	−49	−65	101	130	−54
86	−213	146	−36	70	117	71	71	54	−32	102	−216	−142	−1
87	−52	13	53	−7	206	38	121	−35	−43	−126	−5	−3	13
88	−346	157	−192	131	−72	16	−2	−40	−82	−176	−38	91	−46
89	65	−120	258	170	28	−51	32	15	−93	−65	−82	441	50
90	87	252	−120	109	−33	82	60	−96	−60	−42	112	158	42
91	232	63	−125	115	−27	−45	−146	−29	157	47	−55	224	34
92	−85	307	8	−52	−94	38	15	65	118	85	−44	−148	18
93	−235	−93	−42	−46	−111	82	65	10	23	35	−49	74	−24
94	176	−43	286	137	73	60	82	82	12	113	23	191	99
95	−113	−170	−20	181	73	10	−107	37	107	−103	−55	36	−10
96	248	269	−108	176	195	99	37	110	−82	−42	−77	24	71
97	20	157	−70	59	67	−56	54	10	195	185	40	−87	48
98	126	280	164	37	1	99	65	126	129	−76	−194	−192	47
99	126	−248	−192	76	−16	44	37	10	7	97	251	−81	9
1900	293	−104	−47	126	106	71	−18	110	7	224	−32	30	64
01	126	−148	−14	−52	12	−40	232	76	−88	130	−16	−142	6
02	37	−48	86	−7	67	−112	−74	−101	−121	69	156	−148	−16
03	65	−170	169	−19	34	−140	−74	−74	−105	52	−105	−231	−50
04	−168	−131	8	−141	12	−79	−118	−74	−5	19	101	−98	−56
05	−168	−270	219	−35	−94	−45	−79	49	51	−115	−32	−53	−48
06	243	85	−286	−169	−27	−79	−79	54	112	−42	−82	24	−21
07	15	135	236	−235	−288	−201	−63	−101	−77	−37	−32	102	−46
08	148	41	136	−219	−83	−90	10	−46	34	−59	1	−31	−13
09	109	124	−58	−152	−127	−1	−85	71	−77	−87	218	−442	−42
10	−24	−154	−3	115	−77	−6	48	−46	40	58	−82	−120	−21
11	176	130	153	−52	151	116	−2	−29	90	−76	−266	30	35
12	−380	−87	−286	−2	45	−79	−63	−118	−99	−42	68	19	−85
13	65	−154	−42	59	12	77	15	15	−32	−70	229	230	34

TABLE 18Lc.—States on the Atlantic coast. Mielke's region No. 17.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Jahres-Mittel
Mittel	1.87	2.02	6 21	11.32	16.75	21.12	23.50	22.79	19 87	14.16	8 49	3.54	12.64
1883	−98	231	−215	−32	−25	121	56	−7	−93	12	107	113	14
84	−154	370	51	−65	14	−34	−72	−18	146	128	23	96	32
85	19	−280	−382	−4	−92	5	61	−7	−87	−60	18	29	−65
86	−193	−113	−88	57	−14	−90	−39	−51	41	40	45	−193	−50
87	−15	248	−138	−82	147	−6	139	−40	−148	−60	−66	[−67]	−7
88	−215	137	−210	−38	−81	38	−150	−29	−193	−249	12	−37	−85
89	302	−108	40	85	97	49	−50	−62	−26	−144	145	446	65
90	485	498	−10	62	31	116	−33	−7	41	1	107	−126	97
91	152	370	−93	96	−97	21	−150	60	130	−99	−49	363	59
92	13	154	−154	1	−19	99	−6	93	−37	−27	−43	−32	4
93	−409	87	−99	40	−36	10	44	15	−70	56	−21	74	−26
94	196	48	296	12	64	38	22	−40	124	73	−116	85	67
95	−20	−369	−65	−10	−19	99	−83	99	174	−172	84	113	−14
96	−65	81	−165	146	231	−1	56	99	−4	−105	268	−76	39
97	−76	170	129	29	−31	−40	39	10	−4	95	62	79	39
98	135	87	296	−115	−8	10	33	110	113	367	−14	−15	83
99	7	−196	−4	−32	47	121	0	54	−48	84	51	63	12
1900	69	−24	−143	51	−19	32	83	199	174	240	145	−15	66
01	−15	−258	7	−149	−64	21	111	54	35	−10	−293	−71	−53
02	−131	−180	173	1	31	−51	−17	−68	−43	56	257	−98	−6
03	−15	159	357	7	31	−245	−22	−112	−54	84	−205	−282	−25
04	−365	−285	−54	−160	64	−62	−67	−73	−59	−138	−199	−282	−140
05	−270	−396	51	−4	47	−51	0	−85	−70	−16	−77	2	−72
06	246	−24	−221	68	−14	44	−61	127	130	−49	−21	−110	10
07	130	−246	207	−276	−203	−179	6	−57	46	−210	−71	68	−65
08	−15	−196	185	107	69	16	56	−57	−26	6	23	29	16
09	124	270	−38	29	−44	66	−100	−62	−104	−144	162	−243	−7
10	13	−63	301	157	−325	−101	28	−62	13	90	−216	−371	−45
11	141	42	−104	−99	175	44	72	15	−37	17	−166	213	−26
12	−426	−208	−121	62	58	−45	−17	−79	41	84	−5	168	−41
13	463	−2	212	62	−14	−34	50	−12	−120	62	68	[67]	67

TABLE 19M.—Monthly means of the daily variations of the magnetic declination in Christiania in hundredths of a minute.

Jahr	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Summe	Jahres-Mittel
1860	461	929	1274	997	896	1143	1113	884	815	767	539	291	10109	842
61	277	816	933	1265	1069	1106	876	1026	582	611	868	346	9375	781
62	383	487	781	926	701	1024	977	790	777	833	326	245	8250	688
63	386	597	962	990	957	980	893	867	606	640	343	165	8386	699
64	358	499	818	971	904	896	922	708	431	623	192	95	7417	618
65	130	468	953	893	839	889	693	719	606	434	93	180	6897	575
66	333	570	550	814	860	875	813	699	415	356	329	232	6846	571
67	235	504	786	842	695	861	875	764	552	342	221	153	6830	569
68	308	433	868	1055	754	933	927	914	545	501	384	344	7966	664
69	335	699	845	1074	838	1201	1170	953	884	689	517	204	9409	783
70	406	627	1142	1293	1428	1277	1387	1157	942	1020	722	508	11909	992
71	610	847	1225	1377	1078	1355	1256	1233	972	878	593	419	11843	987
72	670	766	1024	1349	1011	1239	1141	1085	1079	821	567	306	11058	922
73	323	606	1094	1276	892	891	1057	991	783	613	430	315	9274	781
74	399	628	871	1037	902	940	991	845	744	590	411	192	8553	713
75	145	309	787	1005	762	923	768	778	551	330	230	170	6758	563
76	244	220	627	838	603	852	902	760	536	523	292	181	6578	548
77	248	342	537	712	718	825	834	772	512	460	221	48	6229	519
78	60	297	604	757	679	926	845	753	579	342	197	115	6254	521
79	196	330	686	755	741	857	835	837	575	423	233	170	6738	562
80	278	415	694	981	773	921	853	915	773	723	382	101	7809	651
81	274	488	848	933	793	968	949	912	942	661	305	316	8389	699
82	279	508	884	1236	1110	902	803	900	852	524	548	208	8754	729
83	326	491	943	1088	808	950	1011	961	805	827	505	256	8971	748
84	469	771	1075	1174	951	1060	883	794	858	799	483	280	9597	800
85	364	430	896	1049	803	1100	1030	777	692	664	408	248	8461	705
86	475	581	966	899	819	780	905	804	641	553	176	87	7686	641
87	298	313	561	758	652	749	904	765	366	527	266	210	6369	531
88	221	315	670	752	682	891	849	768	497	538	126	196	6505	542
89	155	379	550	712	693	775	791	760	516	494	139	137	6101	508
90	230	459	647	757	608	740	759	612	546	464	243	256	6321	527
91	273	395	641	595	918	838	966	905	616	700	481	218	7546	629
92	357	480	999	986	742	1076	971	931	698	771	480	328	8819	735
93	346	676	1090	1329	1150	1281	1140	1187	956	861	527	455	10994	918
94	462	757	994	1191	1078	999	996	1160	886	648	390	372	9931	828
95	221	482	899	1077	1022	1225	1057	850	802	580	321	209	8741	728
96	268	547	883	1023	893	796	884	845	821	461	288	211	7917	660
97	214	452	800	952	800	740	859	816	635	467	202	227	7161	597
98	189	234	639	629	799	919	797	796	623	541	230	218	6611	551
99	31	372	630	837	674	876	697	751	658	500	279	82	6383	532
1900	112	331	632	735	679	851	747	798	505	471	157	181	6195	516
01	204	281	635	749	765	779	778	654	507	466	151	99	6113	509
02	270	156	420	537	569	750	753	687	425	379	203	168	5317	443
03	319	405	515	839	783	994	822	852	604	405	210	95	6843	570
04	74	355	773	943	735	1069	855	996	795	703	304	200	7802	650
05	358	650	852	936	1139	840	1062	879	784	783	612	294	9189	766
06	400	744	1074	997	835	952	1032	954	591	664	293	165	8701	725
07	196	623	750	882	799	929	791	781	940	807	293	97	7888	657
08	80	406	684	947	706	829	903	785	940	554	235	165	7234	603
09	248	220	654	1052	805	872	753	801	710	576	318	174	7183	599
10	323	281	677	784	666	772	706	723	434	428	213	85	6092	508
11	214	372	553	783	688	641	830	716	563	373	51	−69	5715	476
12	−56	330	669	784	671	658	811	716	484	454	96	160	5777	481
13	298	408	702	778	661	713	765	728	592	459	240	246	6590	549

TABLE 20S.—Monthly means of the daily numbers in tenths (that is 85 = 8.5 and 147 = 14.7) of the solar prominences. First according to observations at the Osservatori del Collegio Romano, second according to observations in Palermo, third according to observations in Catania.

Jahr	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Summe	Jahres-Mittel
1871					147	154	153	154	147	144	138	156		
72	140	137	148	121	119	114	119	120	108	94	114	122	1456	121
73	100	105	90	105	96	84	85	67	78	64	75	77	1026	86
74	64	76	80	73	73	63	64	85	86	93	62	51	870	73
75	52	67	62	55	45	38	50	60	74	69	60	54	686	57
76	73	51	52	64	60	43	54	55	64	49	58	43	666	56
77	54	61	47	52	56	37	52	39	42	30	35	34	539	45
78	27	30	40	35	23	23	35	36	36	38	5	14	342	29
79	34	30	24	26	37	17	32	26	47	59	58	33	423	35
80	26	48	62	51	51	89	91	71	70	87	59	78	783	65
81	72	89	92	118	122	108	108	124	143	134	116	101	1327	111
82	96	111	131	120	89	123	124	100	124	118	99	100	1335	111
83	91	95	64	98	92	92	115	91	80	104	86	87	1095	91
84	76	94	136	119	113	126	117	129	104	130	91	85	1320	110
85	68	102	87	97	110	117	105	97	118	100	106	86	1193	99
86	84	69	51	71	60	61	85	69	80	69	72	78	859	72
87	64	71	63	71	71	90	98	94	95	63	110	83	973	81
88	85	81	103	120	75	88	76	80	69	76	45	41	939	78
89	45	77	73	41	12	9	21	32	38	25	21	17	411	34
90	19	17	22	19	16	24	21	27	29	81	21	34	330	28
91	46	76	61	76	46	56	84	68	93	98	57	65	826	69
92	64	70	81	78	77	106	103	98	111	90	93	95	1066	89
93	81	90	91	116	65	58	62	87	68	58	50	65	891	74
94	60	71	81	50	59	64	47	52	55	46	46	34	665	55
95	26	53	69	71	79	70	78	77	60	45	51	54	733	61
96	52	58	46	33	41	47	43	40	38	69	56	38	561	47
97	37	45	54	39	33	40	26	40	52	49	50	30	495	41
98	27	26	24	34	11	30	21	29	48	41	20	32	343	29
99	39	19	22	27	12	27	20	17	32	30	14	25	284	24
1900	33	12	33	22	30	21	28	23	41	71	33	34	381	32

Jahr	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Summe	Jahres-Mittel
1880		28	20	17	17	29	26	24						
81	40	55	65	42	51	46	73	69	46	56	49	73	665	55
82	64	50	64	59	56	55	52	64	67	63	62	73	729	61
83	70	63	83	82	86	78	70	60	44	63	66	108	873	73
84	80	68	93	89	59	110	85	81	77	68	73	75	958	80
85	59	78	50	62	61	74	91	93	103	99	91	85	946	79
86	70	82	62	37	58	50	58	61	57	65	58	63	721	60
87	59	37	64	37	38	54	59	58	50	46	40	50	592	49
88	40	41	34	30	25	31	27	37	14	31	19	38	367	31
89	22	23	64	24	18	16	22	15	17	19	23	12	235	20
90	11	14	22	17	11	24	23	26	22	37	37	48	291	24
91	59	45	45	13	59	63	82	53	35	82	43	72	651	54
92	62	58	71	71	94	87	89	73	62	38	45	65	815	68
93	52	43	79	83	53	49	50	53	52	61	45	51	671	56

Jahr	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Summe	Mittel
1892	40	42	54	54	56	67	75	62	87	67	67	58	729	61
93	55	68	55	67	37	40	43	70	54	51	31	47	618	52
94	53	54	48	43	42	45	63	49	46	39	36	40	558	47
95	30	21	31	35	33	34	26	42	44	44	28	34	402	34
96	39	37	33	25	33	43	48	56	47	55	35	30	481	40
97	41	54	54	53	41	48	40	47	35	45	52	48	558	46
98	38	42	34	31	24	28	22	39	43	41	34	21	397	33
99	29	29	18	29	25	27	24	14	22	20	9	9	255	21
1900	11	13	15	26	22	8	9	12	12	13	9	13	163	14
01	4	10	6	3	9	11	14	13	8	2	3	4	87	7
02	5	4	4	3	9	6	4	5	4	1	1	3	49	4
03	5	8	8	12	15	11	14	13	11	13	16	16	142	12
04	21	11	36	23	23	31	36	42	22	30	24	28	327	27
05	28	41	44	24	32	28	23	36	33	20	37	9	354	30
06	20	41	57	42	33	32	24	18	4	3	7	13	294	25
07	44	36	57	50	28	23	49	47	55	40	42	51	522	44
08	35	33	60	43	43	41	31	29	17	16	42	26	416	35
09	33	40	49	21	21	29	41	37	49	39	43	36	439	37
10	28	32	50	40	22	24	29	18	23	19	17	13	315	26
11	16	18	15	18	13	20	15	22	12	12	14	9	184	15
12	4	11	11	13	6	12	13	19	17	4	14	13	137	11
13	6	6	13	16	20	9	8	6	8	3	11	11	117	10
14	23	28	13	24	24	29	41	39	33	52	57	61	424	35

EXPLANATION OF PLATES

PLATES 1-14.—Surface temperature in degrees Centigrade of the 2° longitude fields for all of our observational region for each year 1898 to 1910 and each decade group (February 3 to March 4, plates 1-7, March 15 to April 13, plates 8-14). The small numbers at the top on the left for each temperature gives the number of observations in each 2° longitude field and in each decade group. The isotherms for 8°, 10°, 12°, 13°, 14°, 15°, 16° C. are indicated.

PLATE 1, FIGURE 1.—The mean temperatures for the first decade group (February 3 to March 4) for the years 1900 to 1910 in the 2° longitude fields of the shipping route Channel to New York and in the 10° longitude fields of the region Portugal to the Azores. The arrows give the mean isobar directions and mean strength of the air pressure gradients for the 10° longitude fields in the years 1898 to 1908.

PLATE 7, FIGURE 1.—The mean temperatures for the second decade group (March 15 to April 13) for the years 1900 to 1910 in the 2° longitude fields of the shipping route Channel to New York. The arrows give the mean isobar directions and the mean intensity of the air pressure gradients for the 10° fields in the years 1898 to 1908.

PLATE 15.—The charts: fields and stations. The separate numbers give the fields with the surface temperatures. The numbers surrounded by circles give fields or stations with air temperatures.

Fields 1-6: The six 10° longitude fields of the route Channel to New York.

Fields 7-18: The twelve fields of 10° longitude and 2° latitude in the region between Portugal and 40° west longitude.

Fields 19-20: The two Dutch 10° squares.

Fields 21-24: The four 10° longitude fields for the Danish observations between 0° and 40° west longitude and 50° and 60° north latitude.

Fields 25-28: Fields of the Danish observations between 60° north latitude and Iceland.
Field 29: Field of the Danish observations between Scotland and 0° west longitude and between 56° and 57° north latitude.
Station 30: Horns Reef.
Station 31: Vyl.
Station 32: Gjedser Reef.
Station 33: Average of Anholt-Knob and Laoso-Trindel.
Station 34: Skagens Reef.
Station 35: Torungen Lighthouse, 58° 25′ north latitude, 8° 48′ east longitude.
Station 36: Helliso Lighthouse, 60° 45′ north latitude, 4° 43′ east longitude.
Station 37: Ona Lighthouse, 62° 52′ north latitude, 6° 33′ east longitude.
Station 38: Nodoerne Lighthouse, 64° 38′ north latitude, 10° 33′ east longitude.
Station 39: Andenes Lighthouse, 69° 20′ north latitude, 16° 8′ east longitude.
Station 40: Gjesvaer Telegraph Station, 71° 6′ north latitude, 25° 22′ east longitude.
Station 41: Thorshavn, Faeroe Islands.
Station 42: Pápey (Iceland).
Station 43: Vestmanna-Eyar.
Station 44: Stykkisholm.
Station 45: Grimsey.
Station 46: Air temperature for all Iceland (the mean for Reykjavik, Akureyti, Stykkisholm, Grimsey, Berufjord, Vestmannaeyar).
Station 47: Upernivik (Greenland).
Station 48: Godthaab.
Station 49: Ivigtut.
Station 50: Nanortalik.
Station 51: Angmagsalik.
Station 52: Vardo.
Station 53: Sudvaranger.
Station 54: Alten.
Station 55: Tromso.
Station 56: Bodo.
Station 57: Bronnoy.
Station 58: Roros.
Station 59: Christiania.
Station 60: All Norway (22 meteorological principal stations).
Station 61: Sumburgh Head (Shetland Islands).
Station 62: Stornoway (Hebrides).
Station 63: Average of Laudale and Glasgow.
Station 64: Average of Valencia, Blacksod Point and Mackree Castle (Ireland).
Station 65: Scilly Islands.
Station 66: Average for Liverpool, Shields, Oxford, London.
Station 67: Hamburg.

Station 68: Paris (Meteorological Institute).
Station 69: Brest.
Station 70: Biarritz.
Station 71: Madrid.
Station 72: Coimbra.
Station 73: Lisbon.
Station 74: San Fernando.
Station 75: Ponta Delgada.
Station 76: Horta.
Station 77: Funchal (Madeira).
Station 78: Las Palmas (Canary Islands).
Station 79: St. Louis.
Station 80: Dakar.
Station 81: Kayes.
Station 82: Arequipa, Peru (16° 25′ south latitude).
Station 83: Cayenne.
Station 84: Fort de France.
Station 85: St. Croix.
Station 86: Port au Prince (Haiti).
Station 87: Bermuda.
Station 88: Key West.
Station 89: Jacksonville.
Station 90: New Orleans.
Station 91: Galveston.
Station 92: Knoxville.
Station 93: Mean of Washington, Baltimore, and Philadelphia.
Station 94: Atlantic City.
Station 95: New York.
Station 96: Boston.
Station 97: Eastport.
Station 98: Halifax.
Station 99: White Head.
Station 100: Sydney.
Station 101: St. Johns.
Station 102: Cape Norman.
Station 103: Belle Isle.
Station 104: Cape Magdalena.
Station 105: Chatham.
Station 106: Anticosti.
Station 107: Father Point (Quebec).
Station 108: Quebec.
Station 109: Montreal.
Station 110: Ottawa.
Station 111: Toronto.
Station 112: St. Louis.
Station 113: Duluth.

PLATE 15.—Isopleth diagrams below: Mean temperatures of the surface in the 4° longitude fields of the shipping course Channel to New York for each decade (I-VII) in the time interval 1900 to 1910.

PLATES 16-41.—The charts. The separate numbers give the anomalies of the surface temperatures in tenths of a degree Centigrade. The numbers in circles give the anomalies of the air temperatures in tenths of a degree Centigrade. The heavy verticle numbers give positive anomalies, the inclined weak numbers give negative anomalies. The heavy rings indicate positive, the weak negative anomalies.

PLATES 16-40.—The curve-diagrams at the bottom on the left side. For explanation see the text.

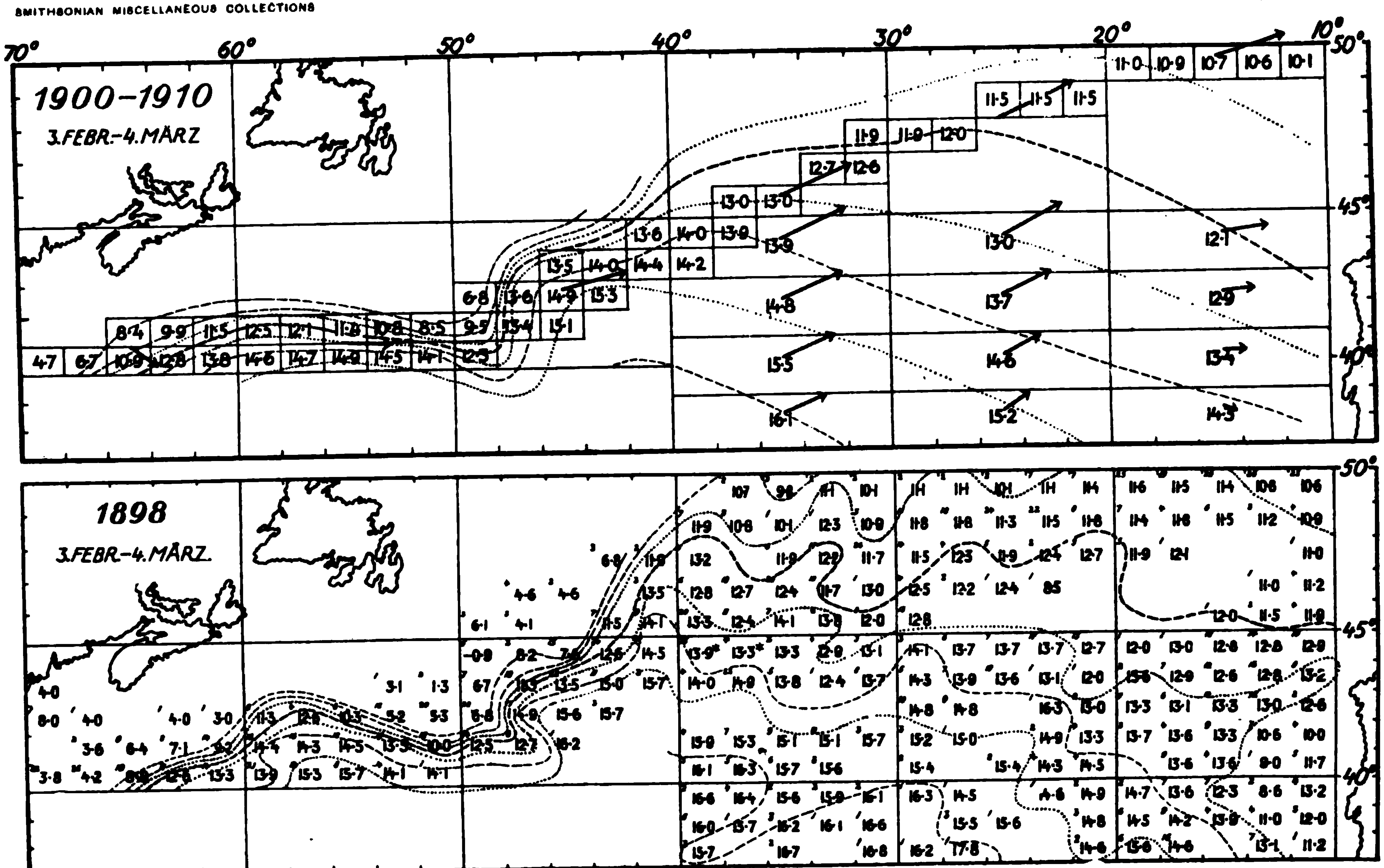
PLATES 15-41. The isopleth-diagrams at the bottom on the right side give the anomalies of the surface temperatures in tenths of a degree Centigrade for each decade (I-VII) for the 4° longitude fields of the shipping course Channel to New York. The heavy vertical numbers give the positive anomalies, the lighter inclined numbers negative anomalies.

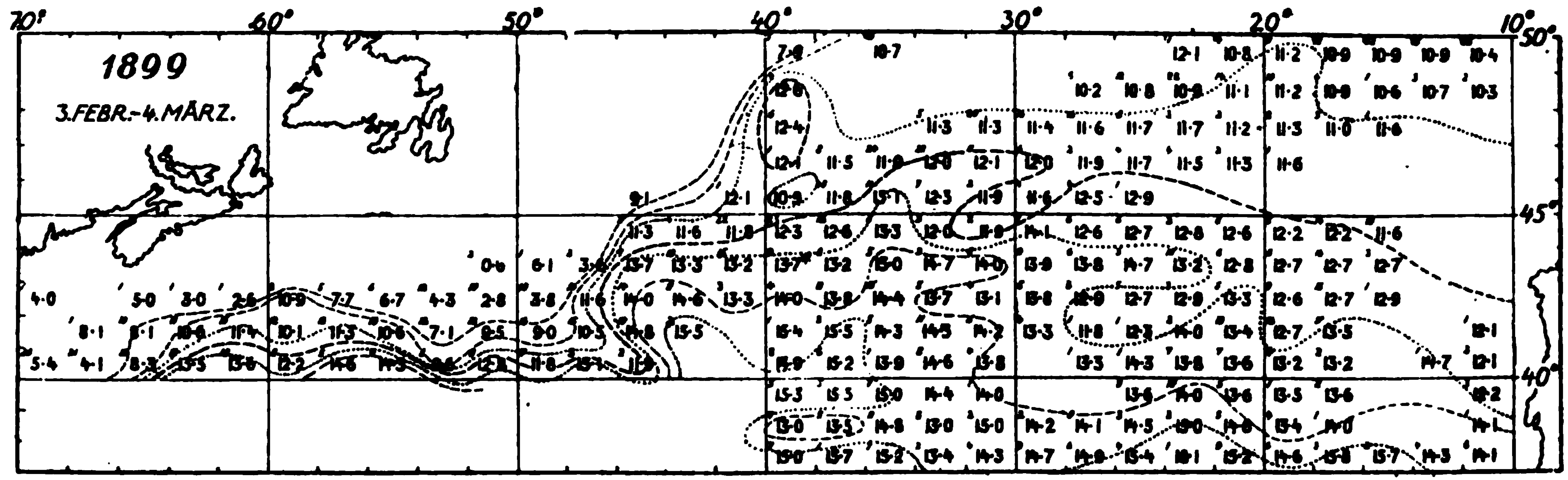
PLATES 42 AND 43.—Pressure gradient-curves and temperature-curves for the 10° longitude fields of the shipping course Channel to New York (see also plate 15, 1-6) for the first decade group February 3 to March 4, and for the second decade group March 15 to April 13. Curves B: Anomalies of the relative numbers of the air pressure gradients for the months January to March and the mean for January and February (strong dotted lines). Curve W: Anomalies of the surface temperature for February 3 to March 4, and for March 15 to April 13. Curves L: Anomalies of the air temperature for the same time as for W. W-L: Anomalies of the difference surface temperature minus air temperature for the same time as for W. For each temperature curve for each decade group mean values are given for the series of years 1900-1910 under the headings W, L, and W-L.

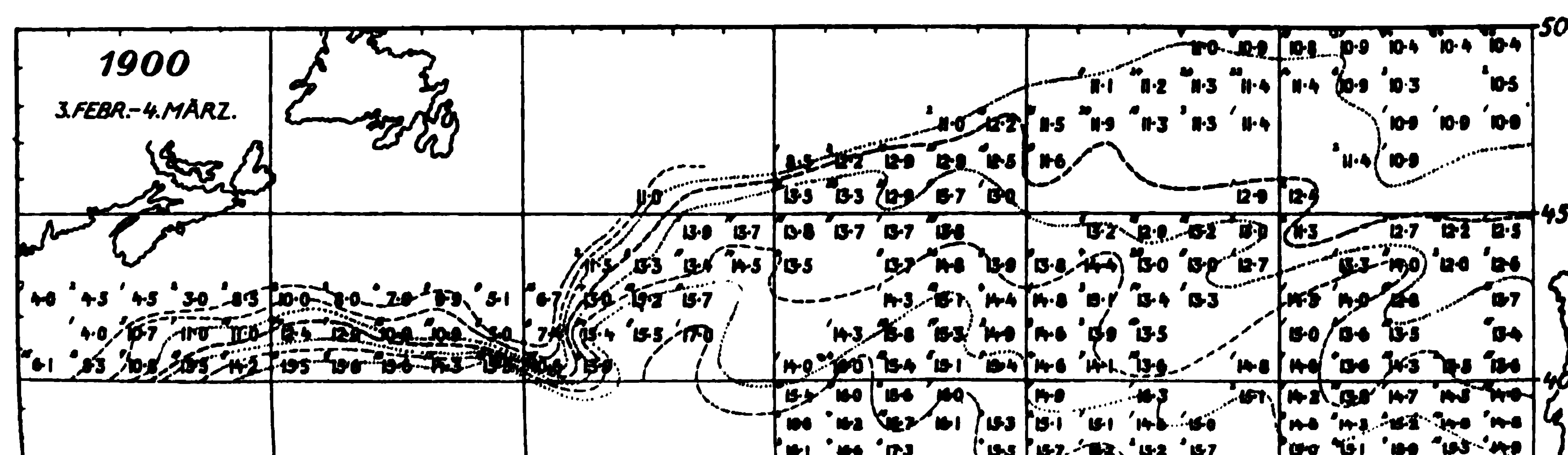
PLATES 44 AND 45.—Pressure gradient curves and temperature curves for the southerly region Portugal to the Azores for the first decade group February 3 to March 4. Explanation of these curves is the same as for plates 42 and 43.

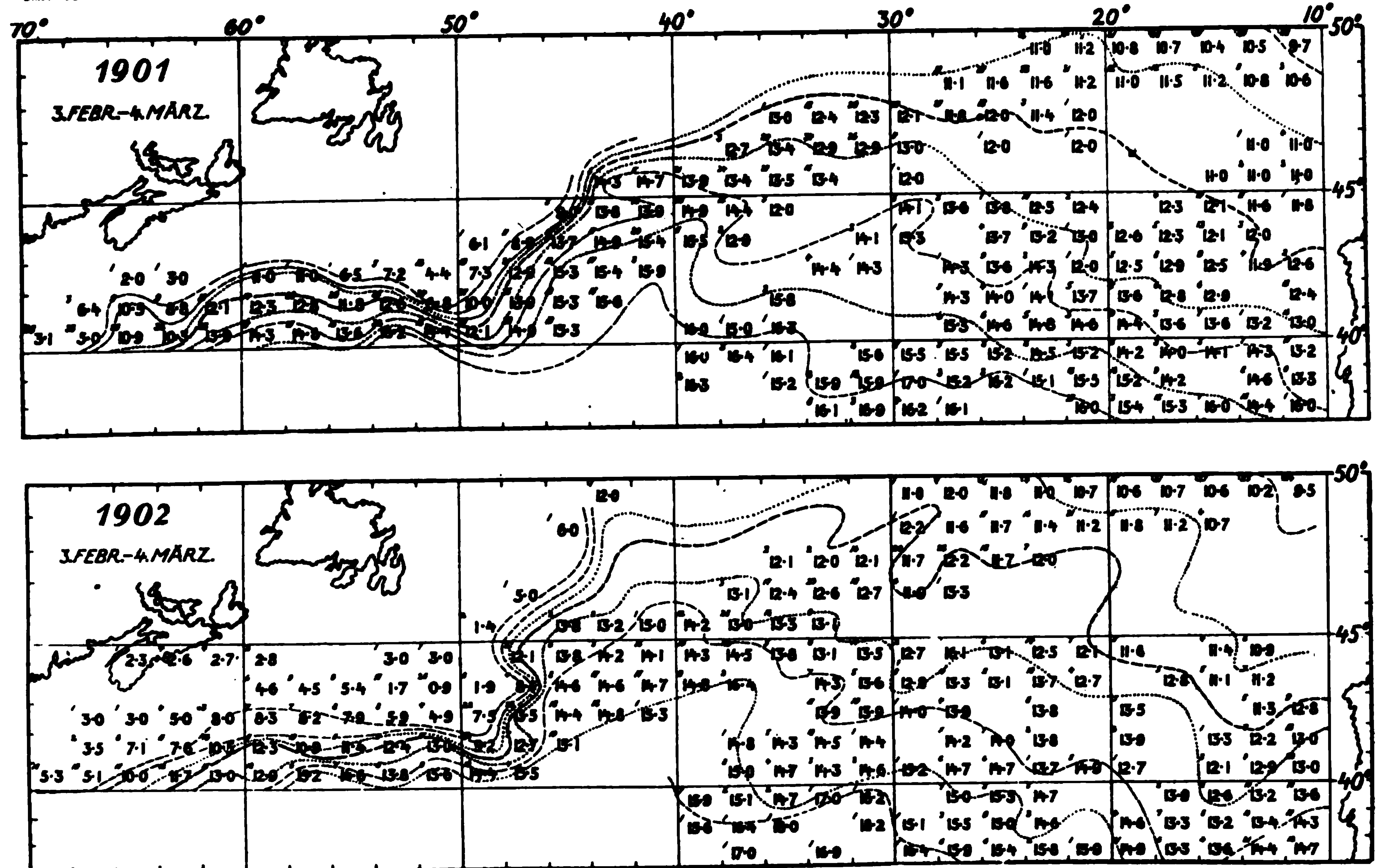
PLATE 46.—Air pressure gradient curves and temperature curves for the four 10° longitude fields of the Danish observational region for February and for March 16 to April 15. Explanation of the curves is the same as for plates 42 and 43. The curves L in the two lower diagrams give the mean air temperature for Stornoway (Hebrides), Deerness (Orkney), and Sumburgh Head (Shetland).

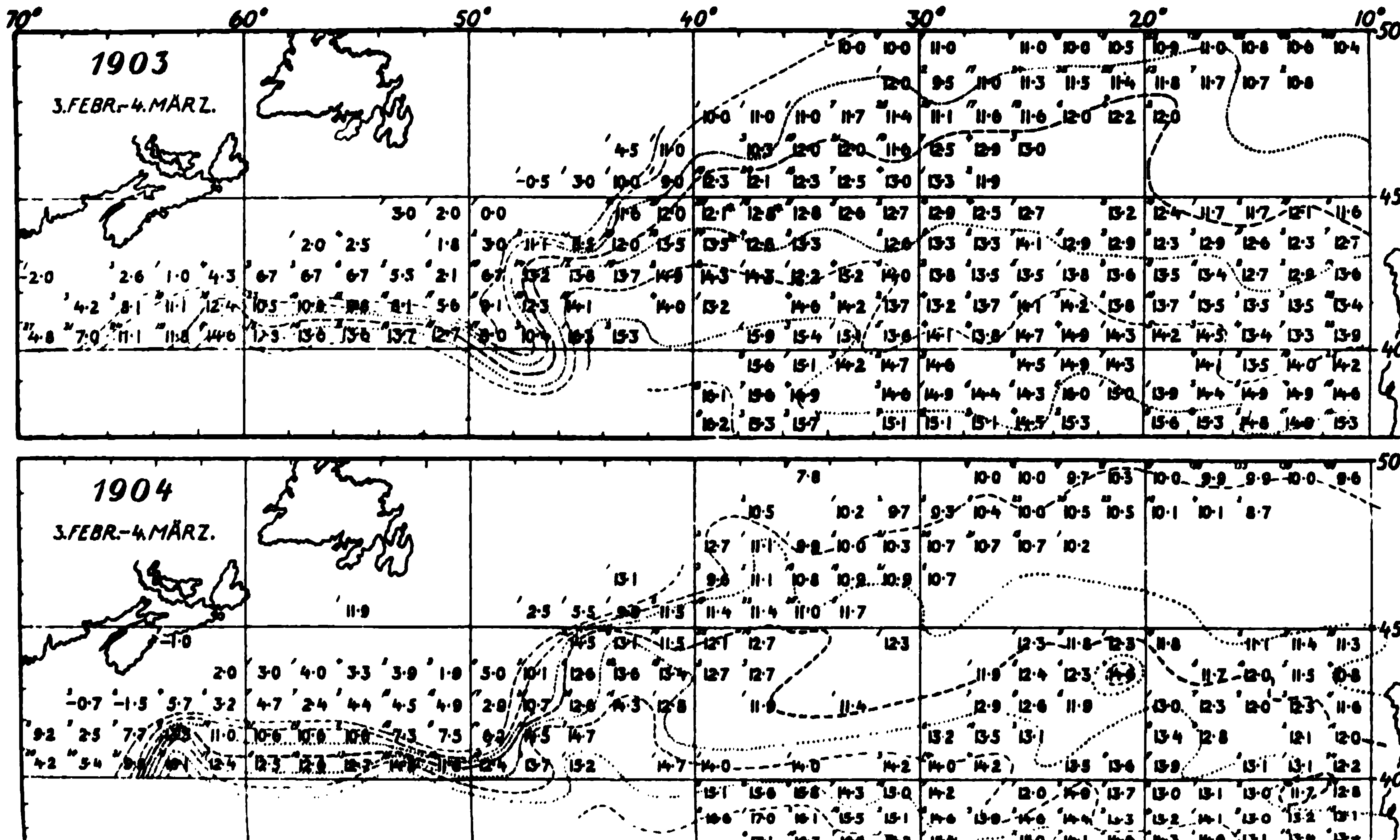
PLATES 47 AND 48.—Air pressure gradient curves (B) and temperature curves (W water, L air) for various stations on the Norwegian coast.

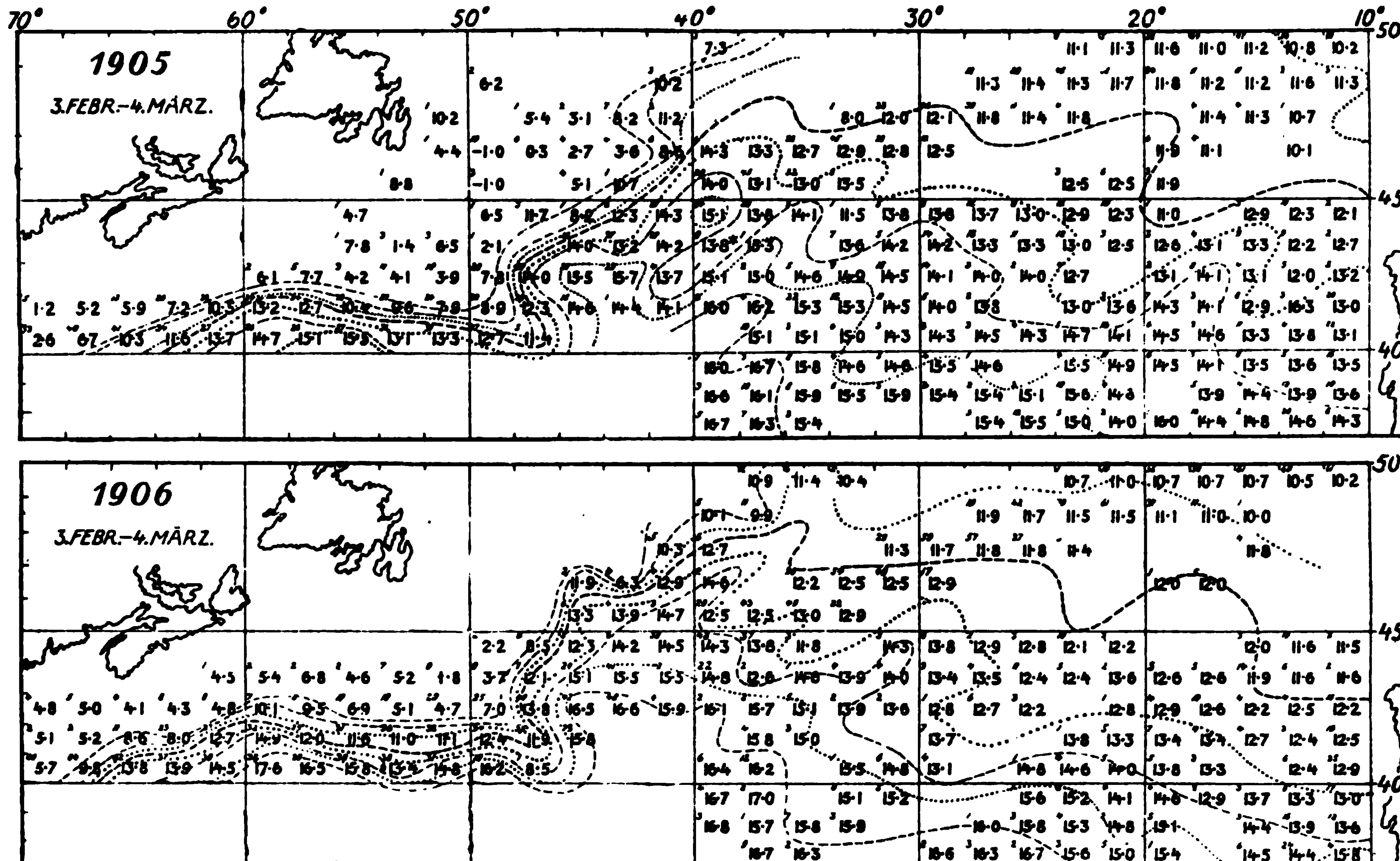

1900–1910
3.FEBR.-4.MÄRZ
1898
3.FEBR.-4.MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

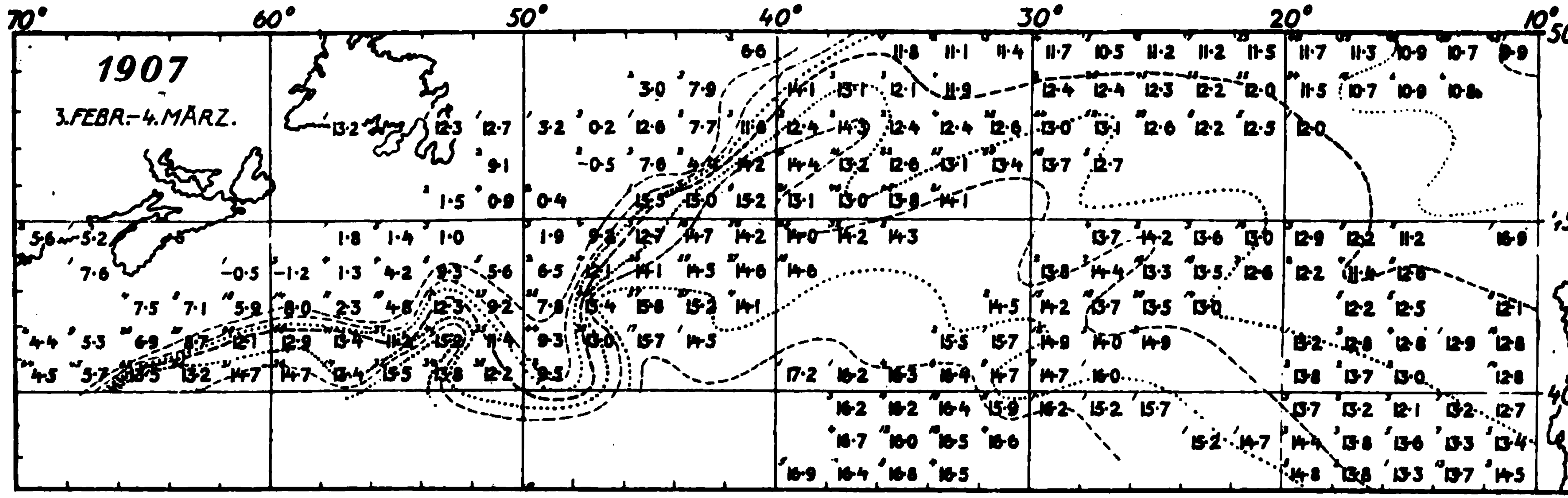

1899
3.FEBR.-4.MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

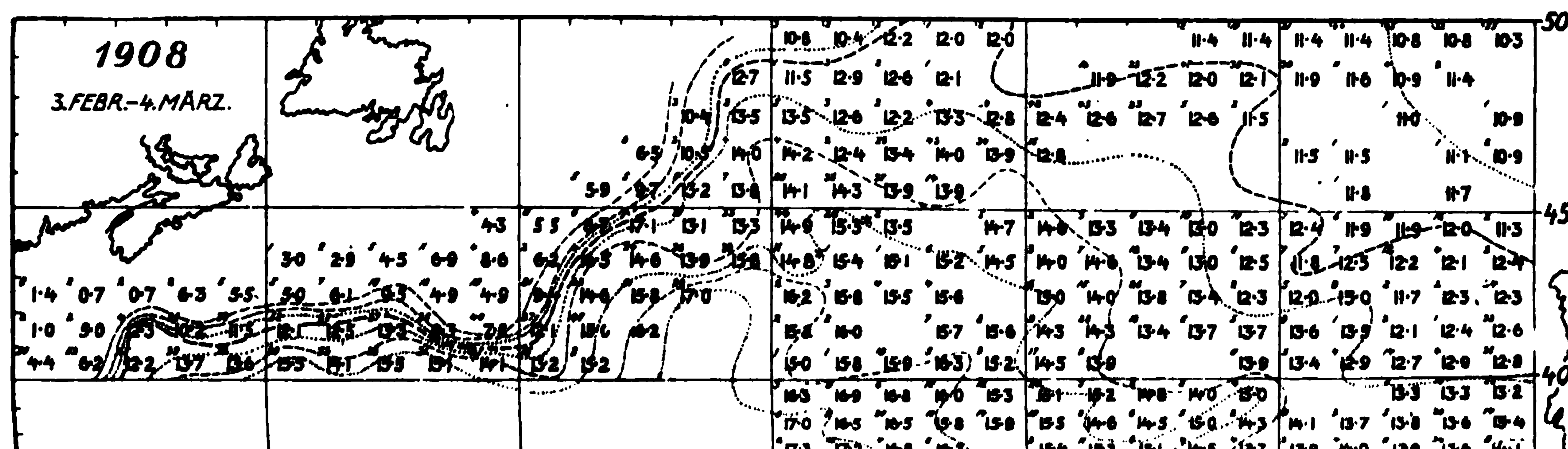

1900
3.FEBR.-4.MÄRZ.
50°
45°
40°

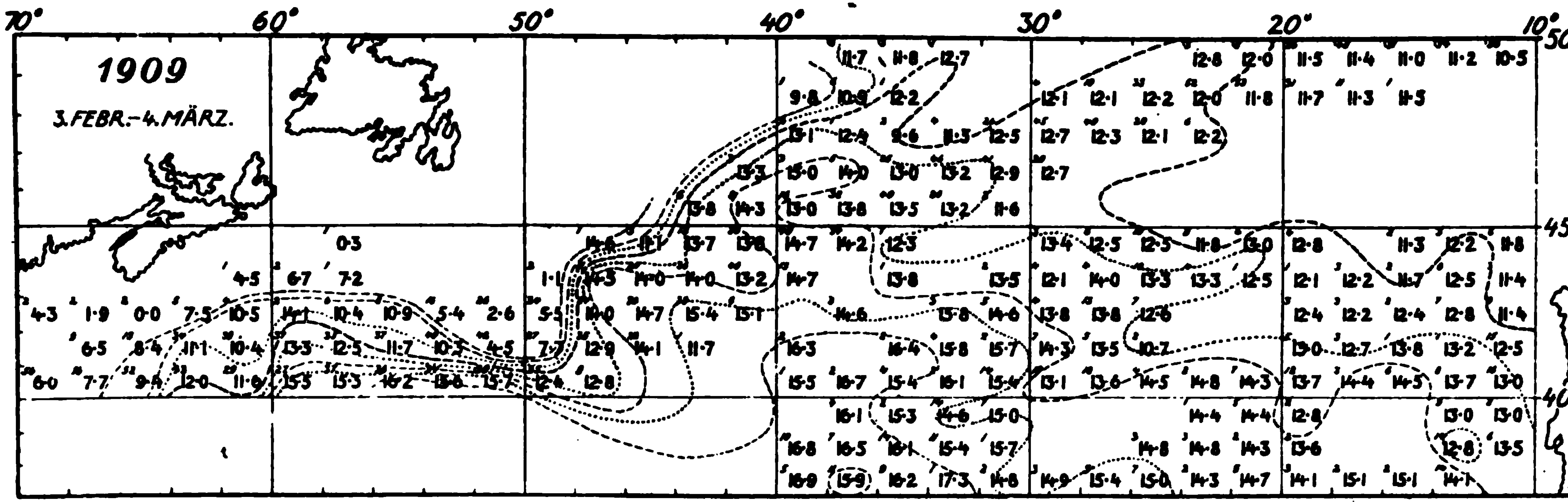

1901
3.FEBR.–4.MÄRZ
1902
3.FEBR.–4.MÄRZ
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°
III.

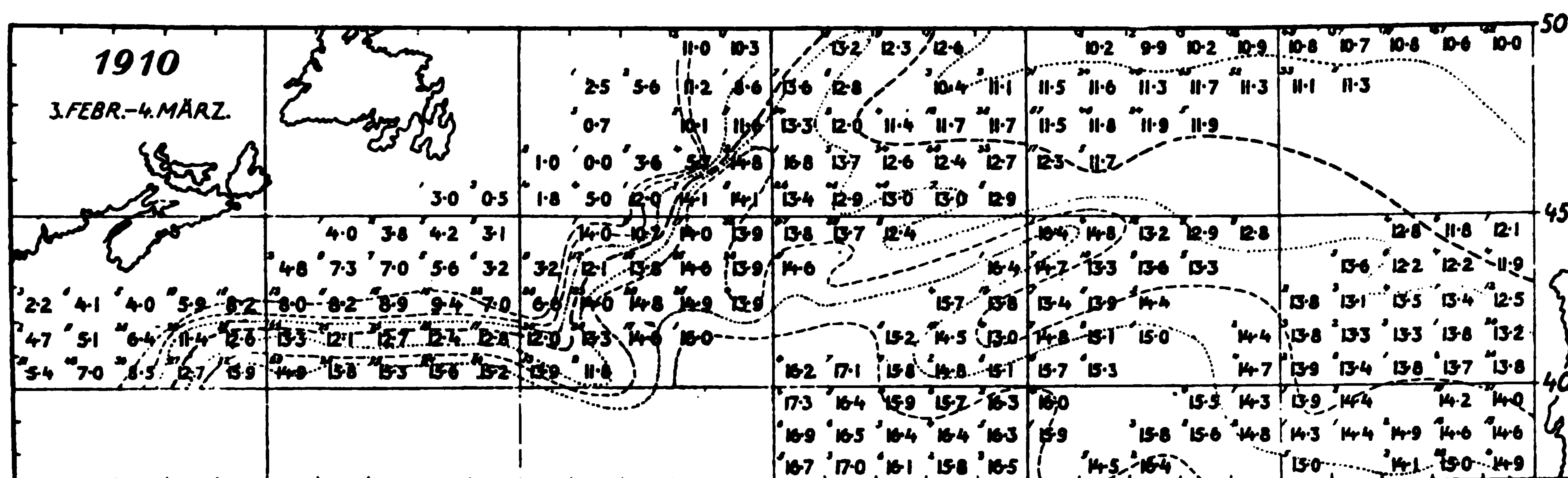

1903
3. FEBR.-4. MÄRZ.
1904
3. FEBR.-4. MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

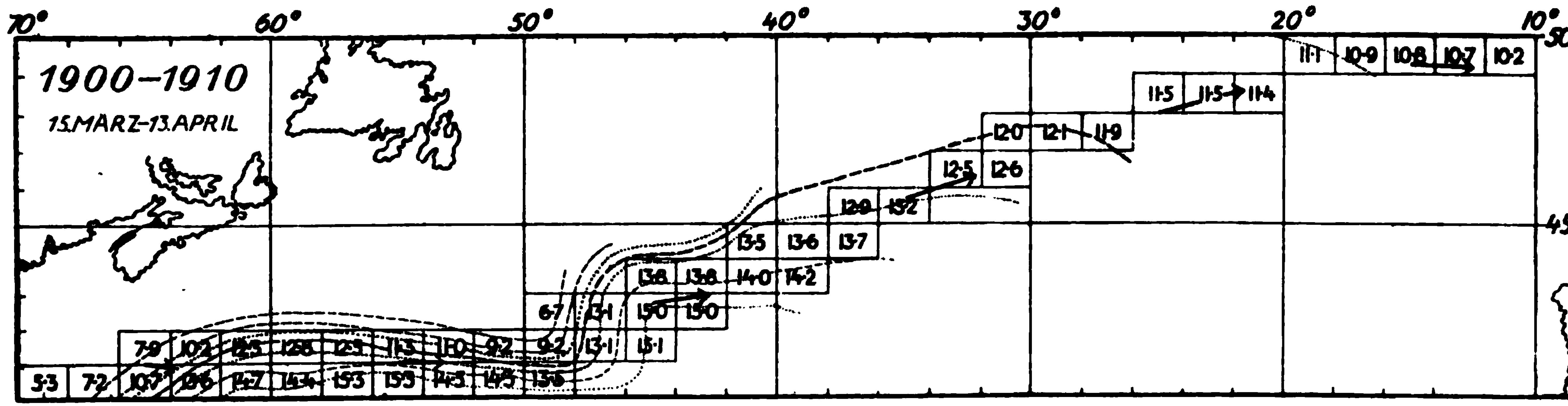

1905
3.FEBR.–4.MÄRZ.
1906
3.FEBR.–4.MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

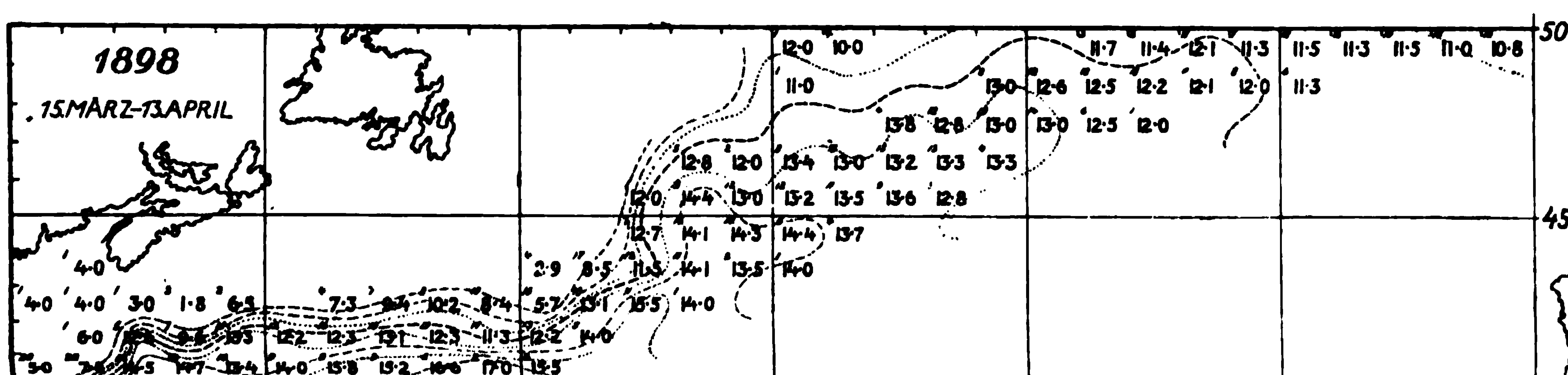

1907
3.FEBR.–4.MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

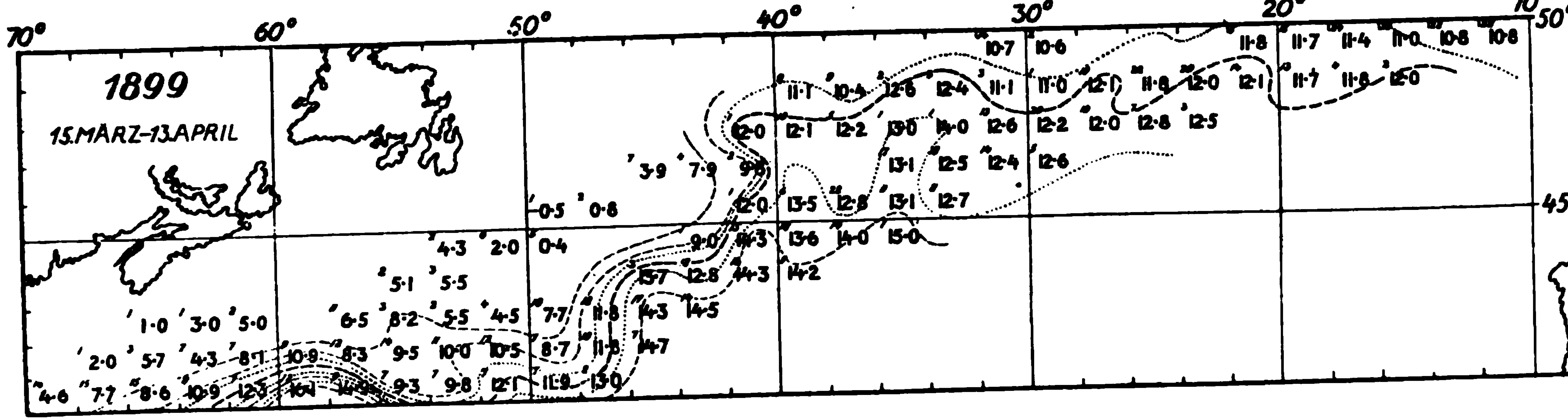

1908
3.FEBR.–4.MÄRZ.
50°
45°
40°

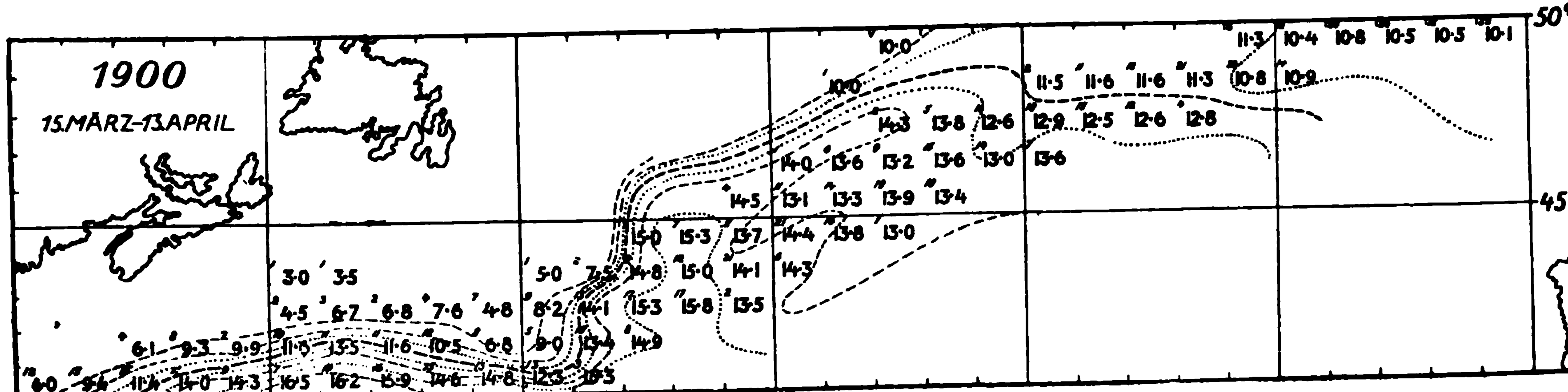

1909
3. FEBR.–4. MÄRZ.
70°
60°
50°
40°
30°
20°
10°
50°
45°
40°

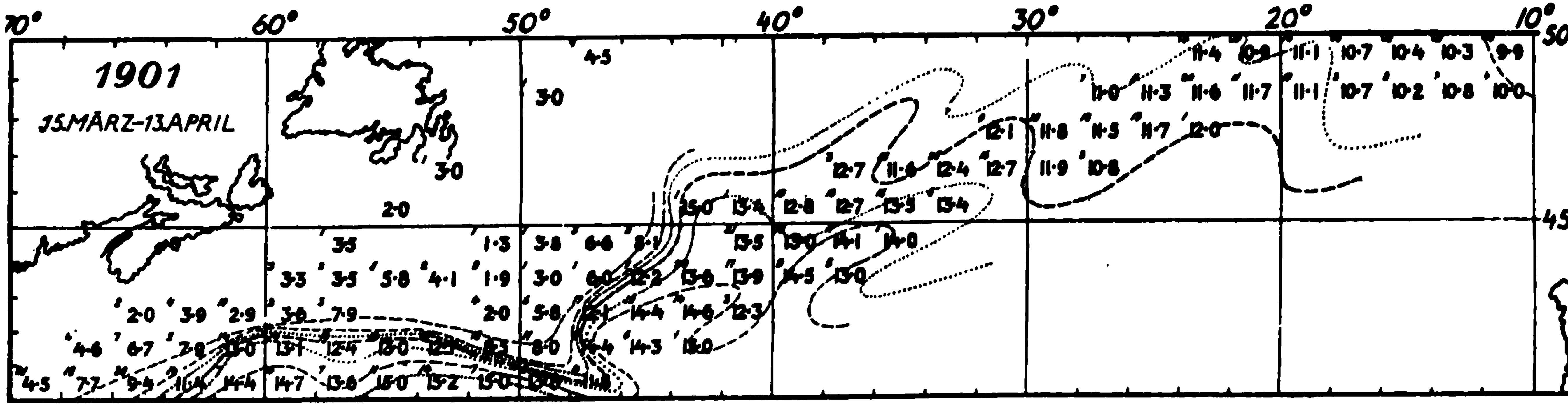

1910
3. FEBR.–4. MÄRZ.
50°
45°
40°

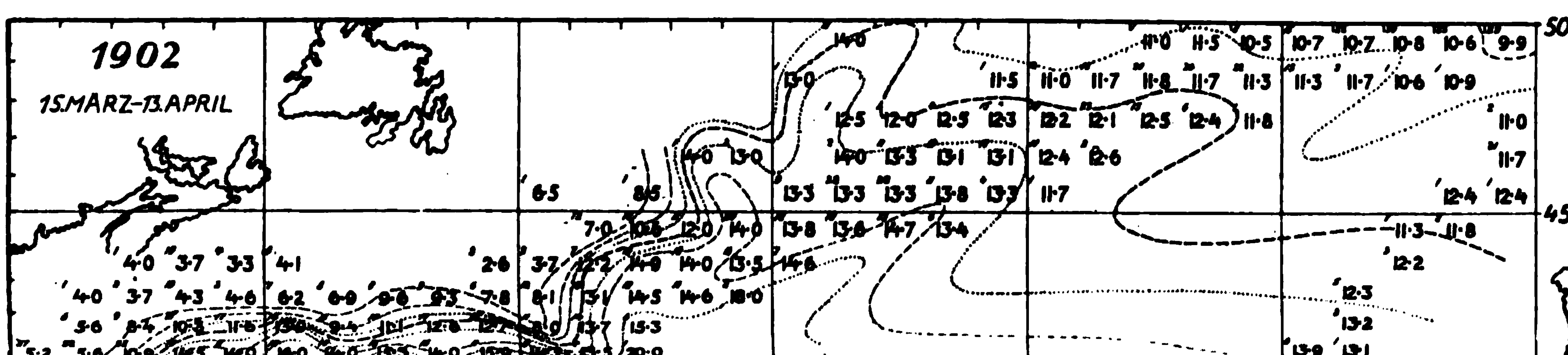

1900–1910
15.MÄRZ–13.APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°

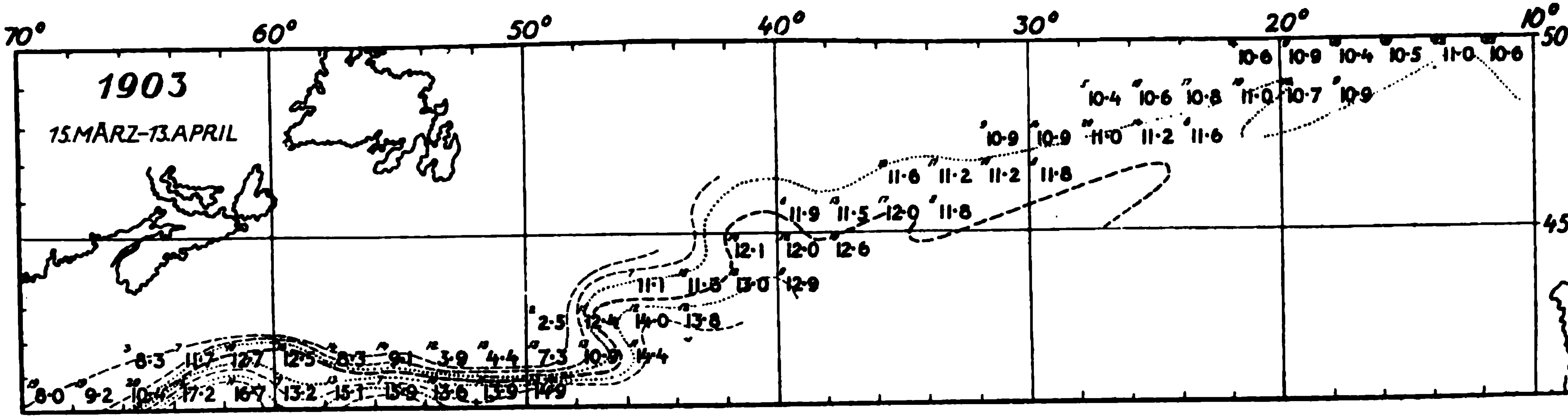

1898
15.MÄRZ–13.APRIL
50°
45°

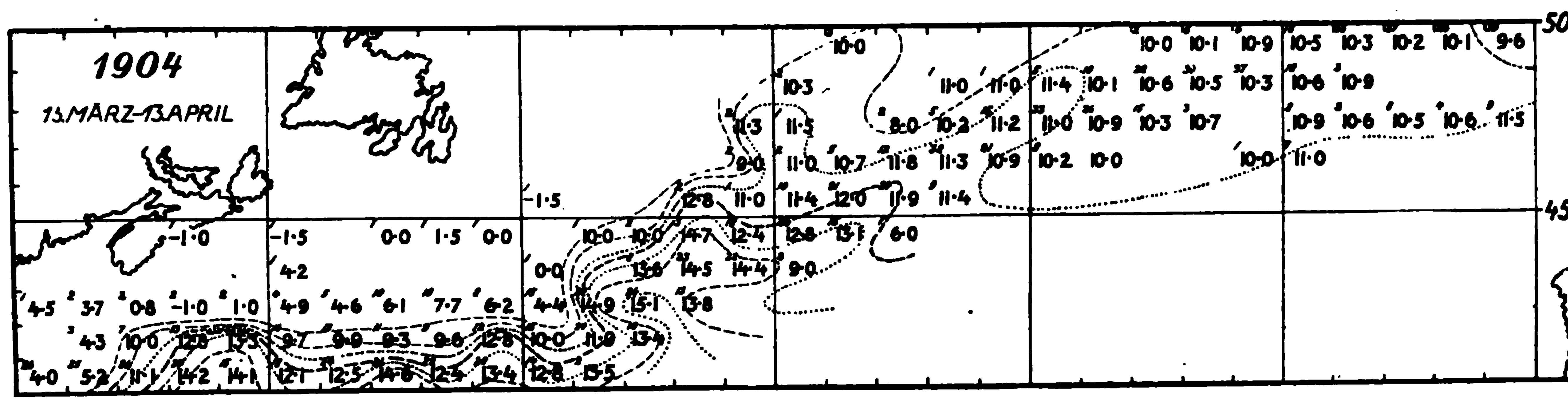

1899
15.MÄRZ–13.APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°

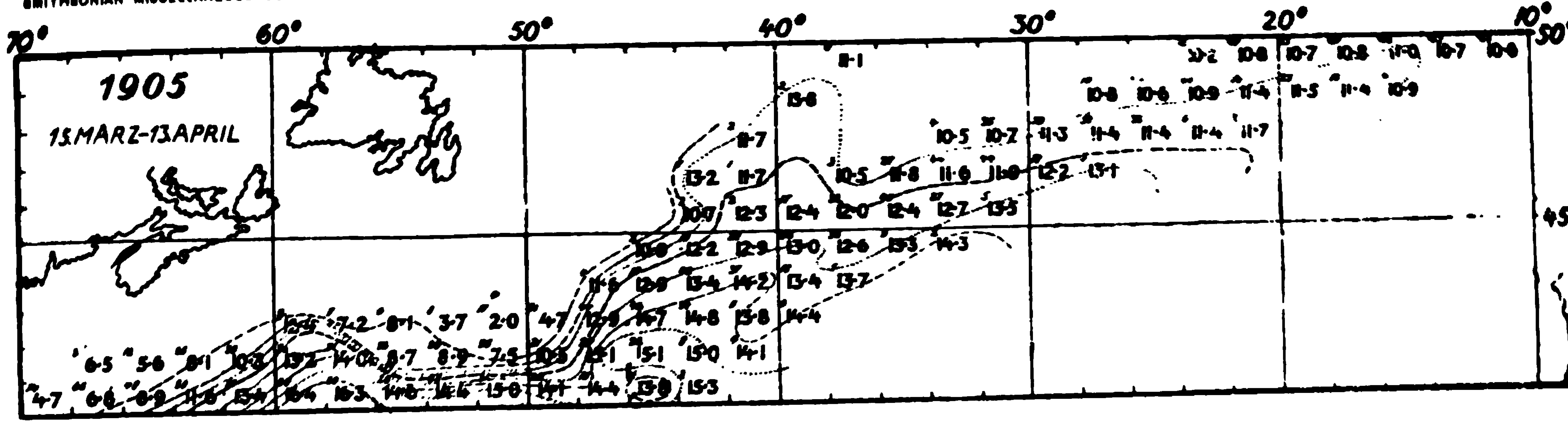

1900
15.MÄRZ–13.APRIL
50°
45°

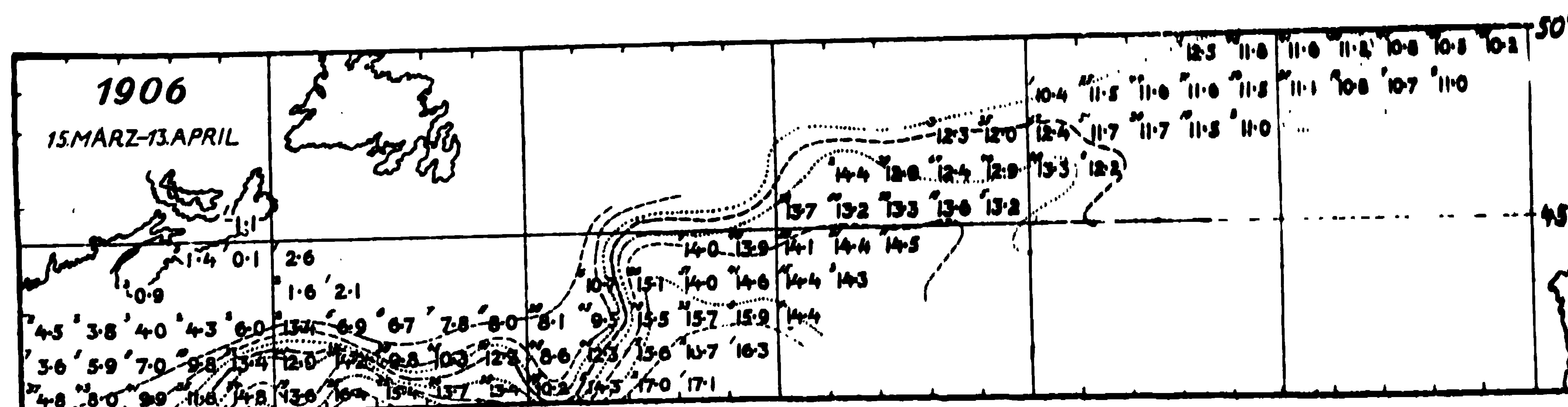

1901
15. MÄRZ–13. APRIL

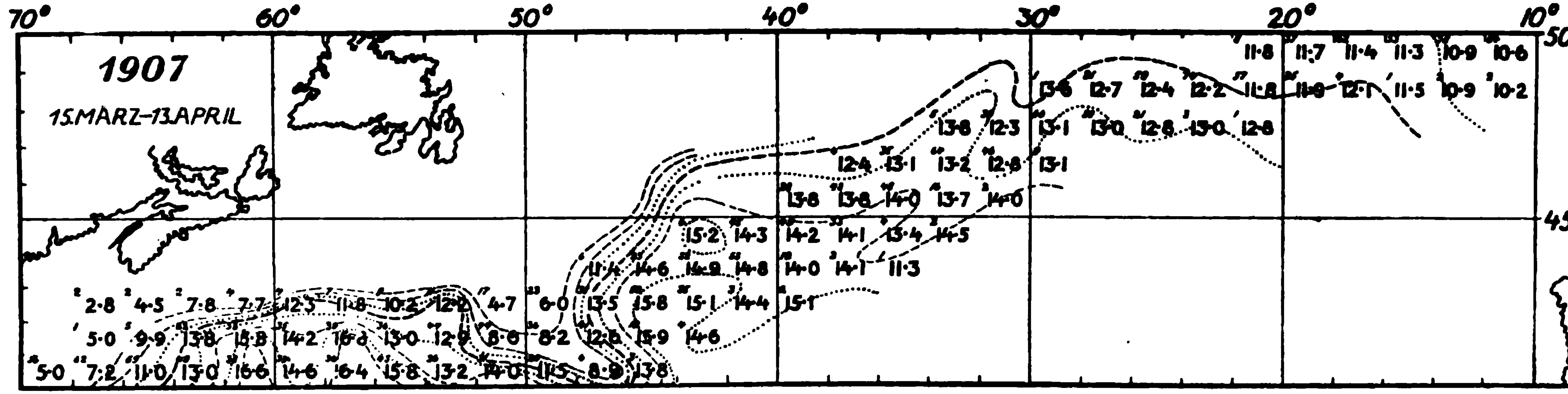

1902
15. MÄRZ–13. APRIL

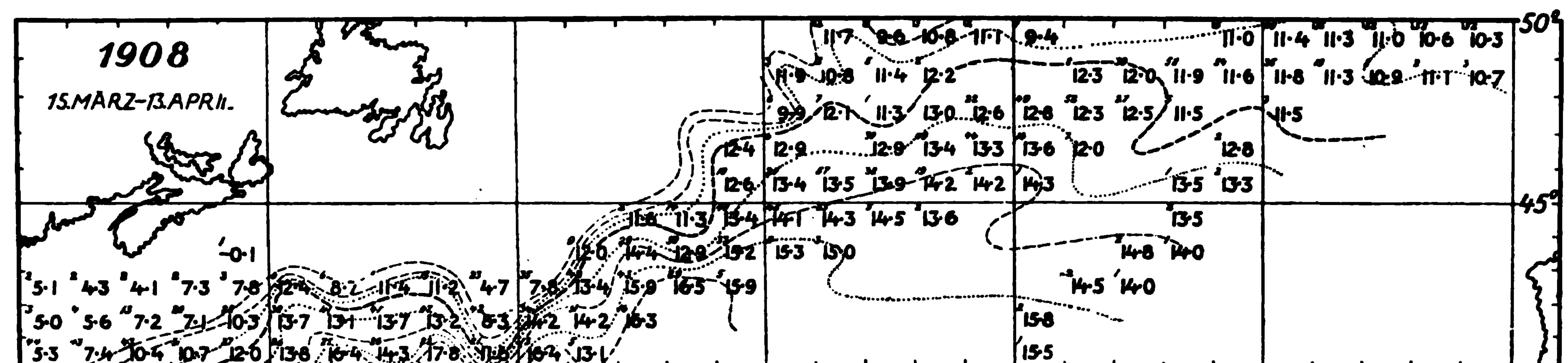

1903
15.MÄRZ-13.APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°

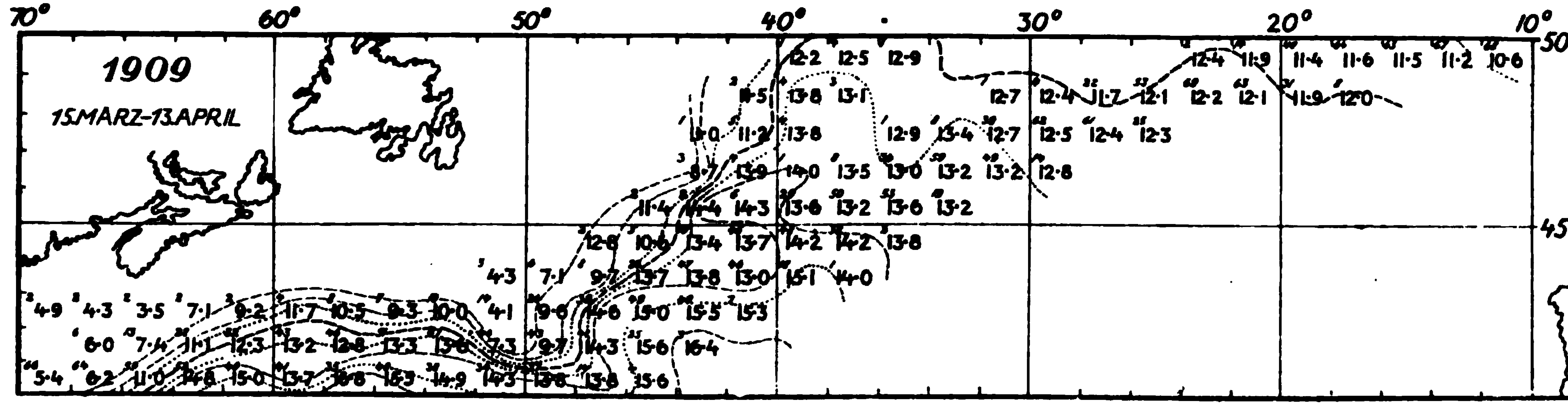

1904
13.MÄRZ-13.APRIL
50°
45°

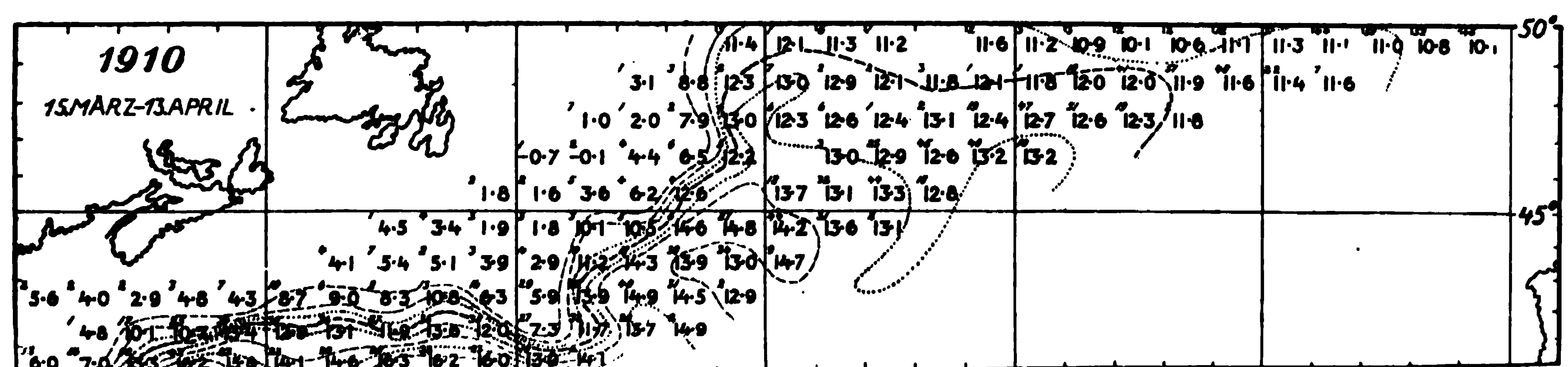

1905
15. MÄRZ–13. APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°

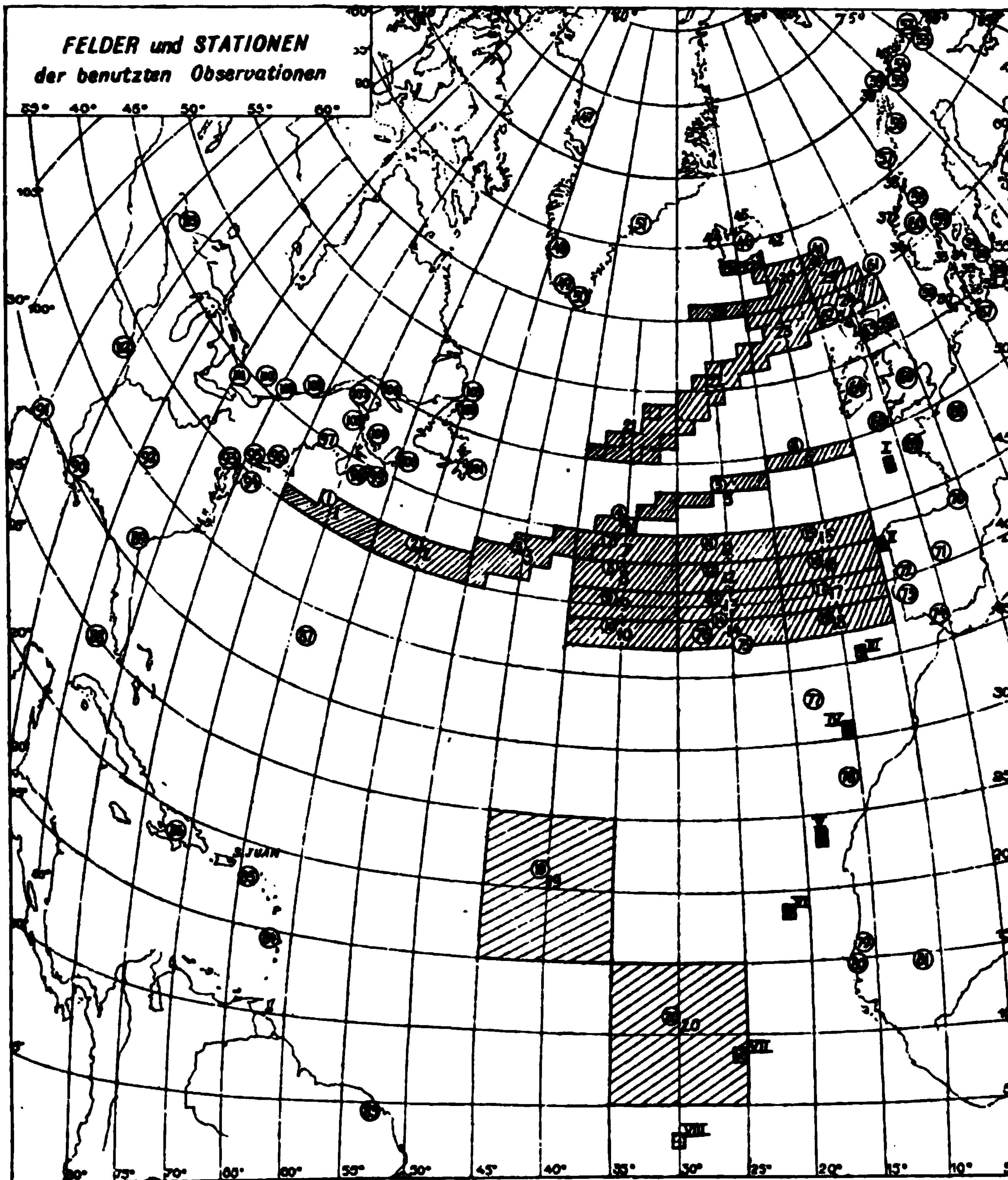

1906
15. MÄRZ–13. APRIL
50°
45°


1907
15.MÄRZ–13.APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°


1908
15.MÄRZ–13.APRIL.
50°
45°

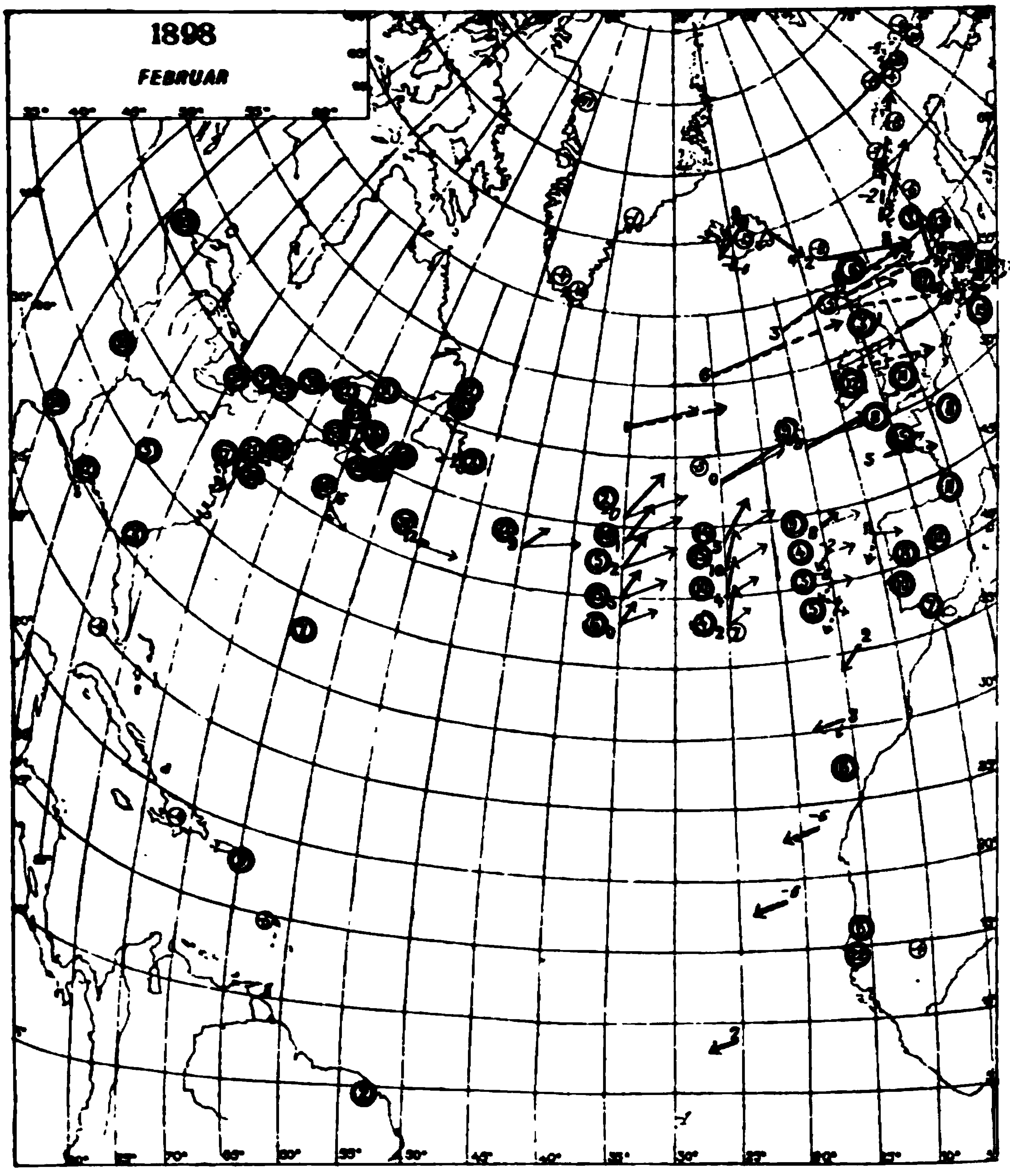

1909
15.MÄRZ-13.APRIL
70°
60°
50°
40°
30°
20°
10°
50°
45°

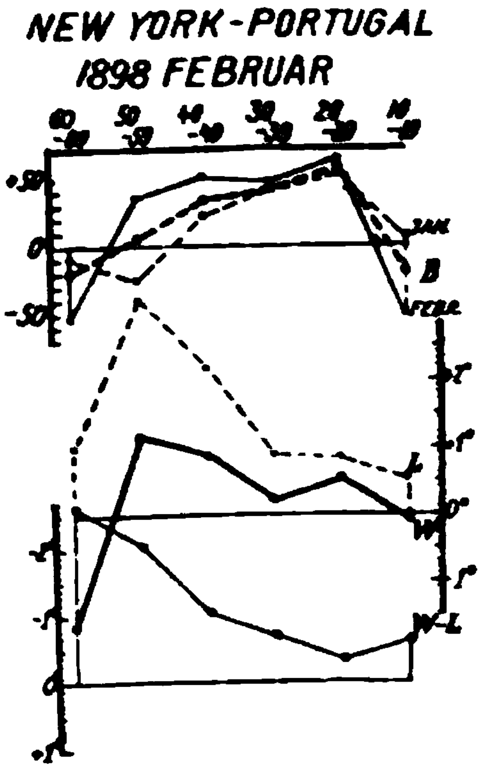

1910
15.MÄRZ-13.APRIL
50°
45°

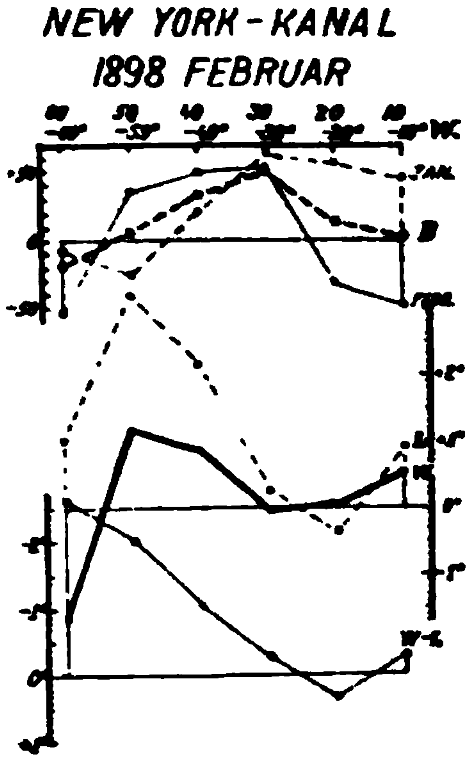


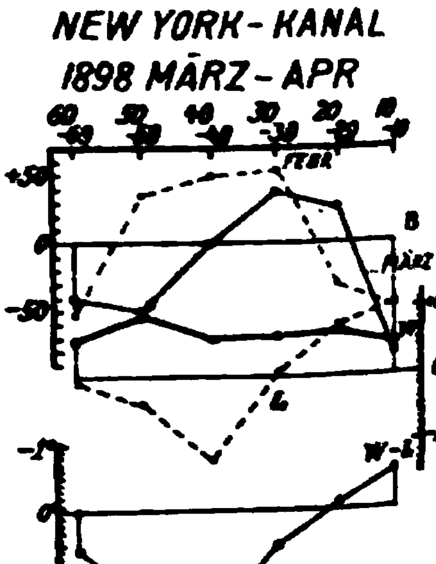
MITTEL = Temperaturen der Oberfläche der Vier = Längengrad = FELDER fur jede Dekade im Zeitraum 1900 – 1910.

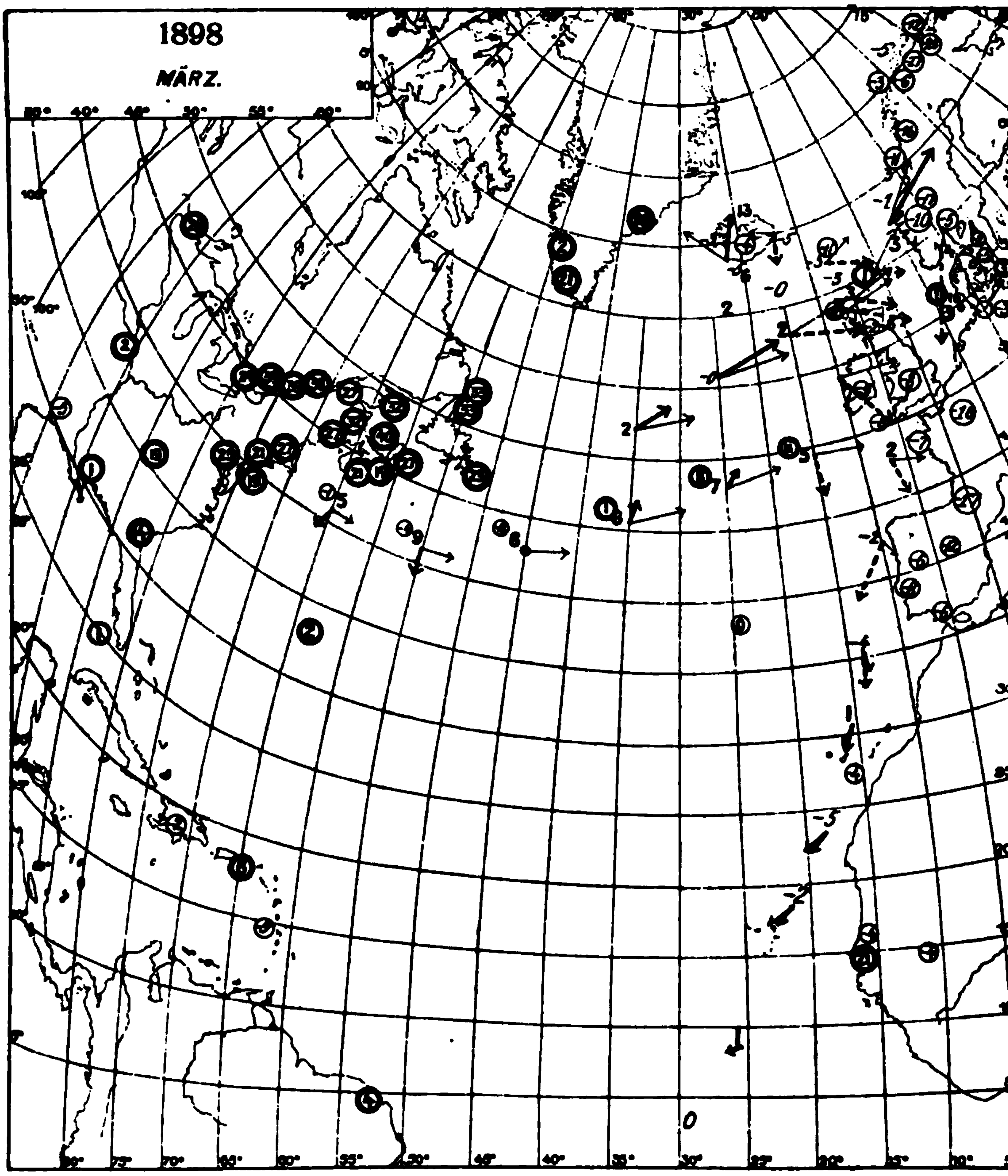
DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	6·2	10·6	13·2	13·6	11·7	11·4	14·8	14·4	13·6	12·6	12·1	11·6	11·2	10·8	10·3
II	5·8	10·2	12·9	12·9	12·0	11·1	14·5	13·9	13·2	12·3	11·8	11·6	11·3	10·8	10·4
III	5·2	10·2	13·2	13·1	11·8	11·1	14·5	13·9	13·1	12·3	11·8	11·5	11·2	10·8	10·4
I	5·9	11·1	13·3	13·3	12·2	11·0	14·4	13·5	12·9	12·0	11·8	11·4	11·0	10·7	10·2
II	6·2	10·3	13·5	13·6	12·2	10·7	14·5	13·8	13·3	12·4	12·0	11·5	11·3	10·8	10·4
III	7·0	10·9	13·7	13·9	12·3	11·2	14·7	14·0	13·6	12·8	12·3	11·7	11·4	11·1	10·6


1898
FEBRUAR


NEW YORK-PORTUGAL
1898 FEBRUAR
JAN.
B
FEBR.
L
W
W-L

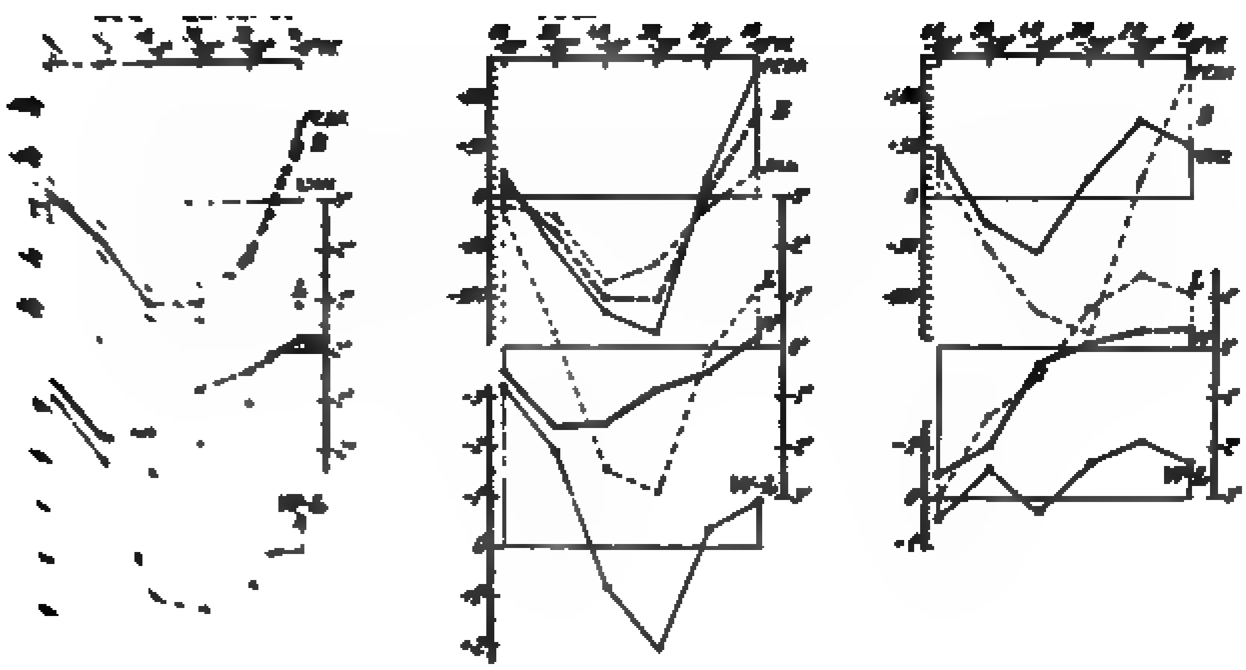

NEW YORK-KANAL
1898 FEBRUAR
JAN.
B
FEBR.
L
W
W-L

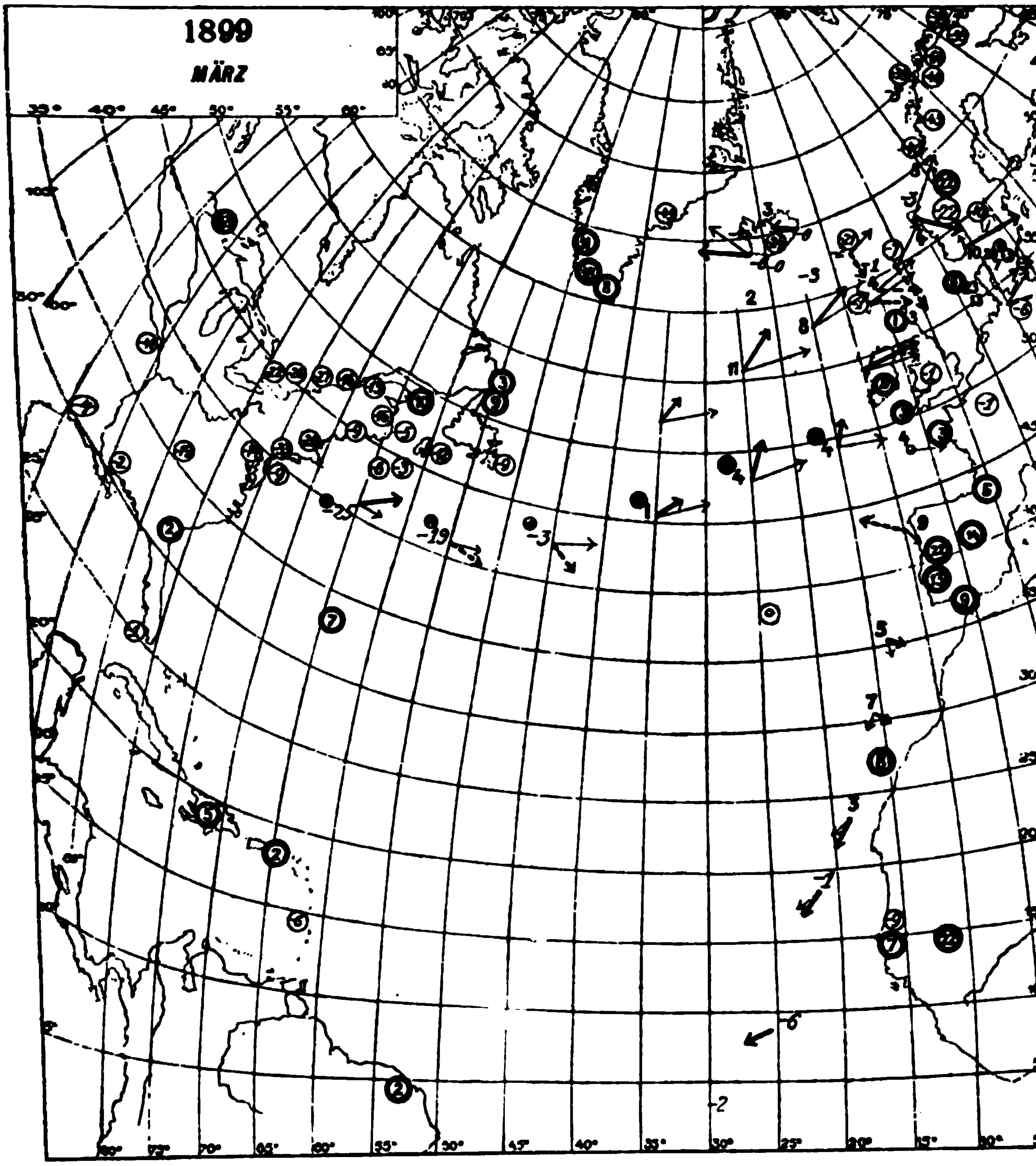

NEW YORK-KANAL
1898 MÄRZ-APR
FEBR.
B
MÄRZ
L
W-L



1898

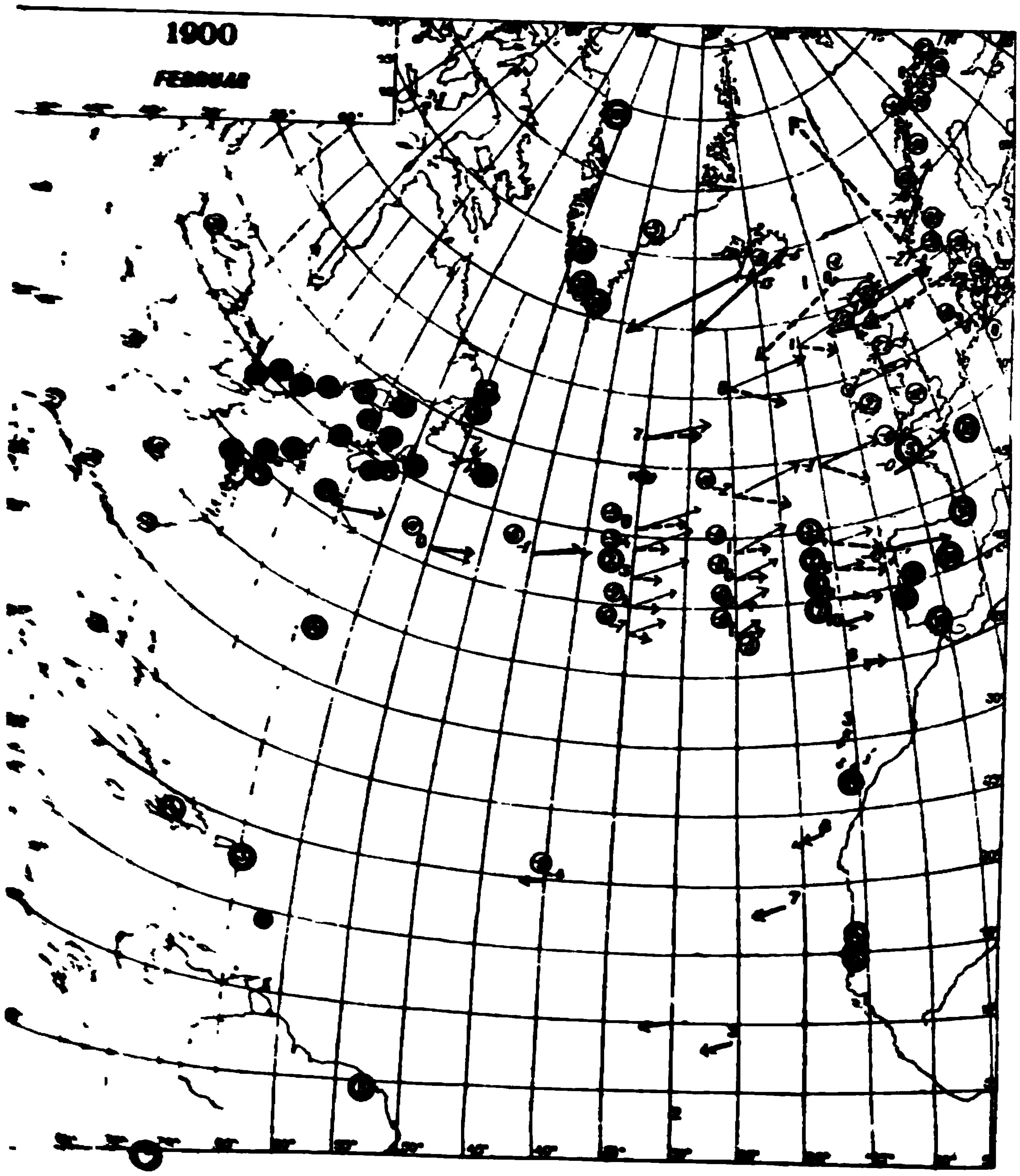
DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	33	46	2	3	8		3	2	3		5	1	7	5	2
II	16	1	10	29							7	3	6	8	4
III	8	22	8	12						6		2	1	8	7
IV	7	13	15	7						17	8		5	3	5
V	11		2	15				4	8	6	8	4	3	2	0
VI	8	10	0	16					2	0	1	7	7	8	9

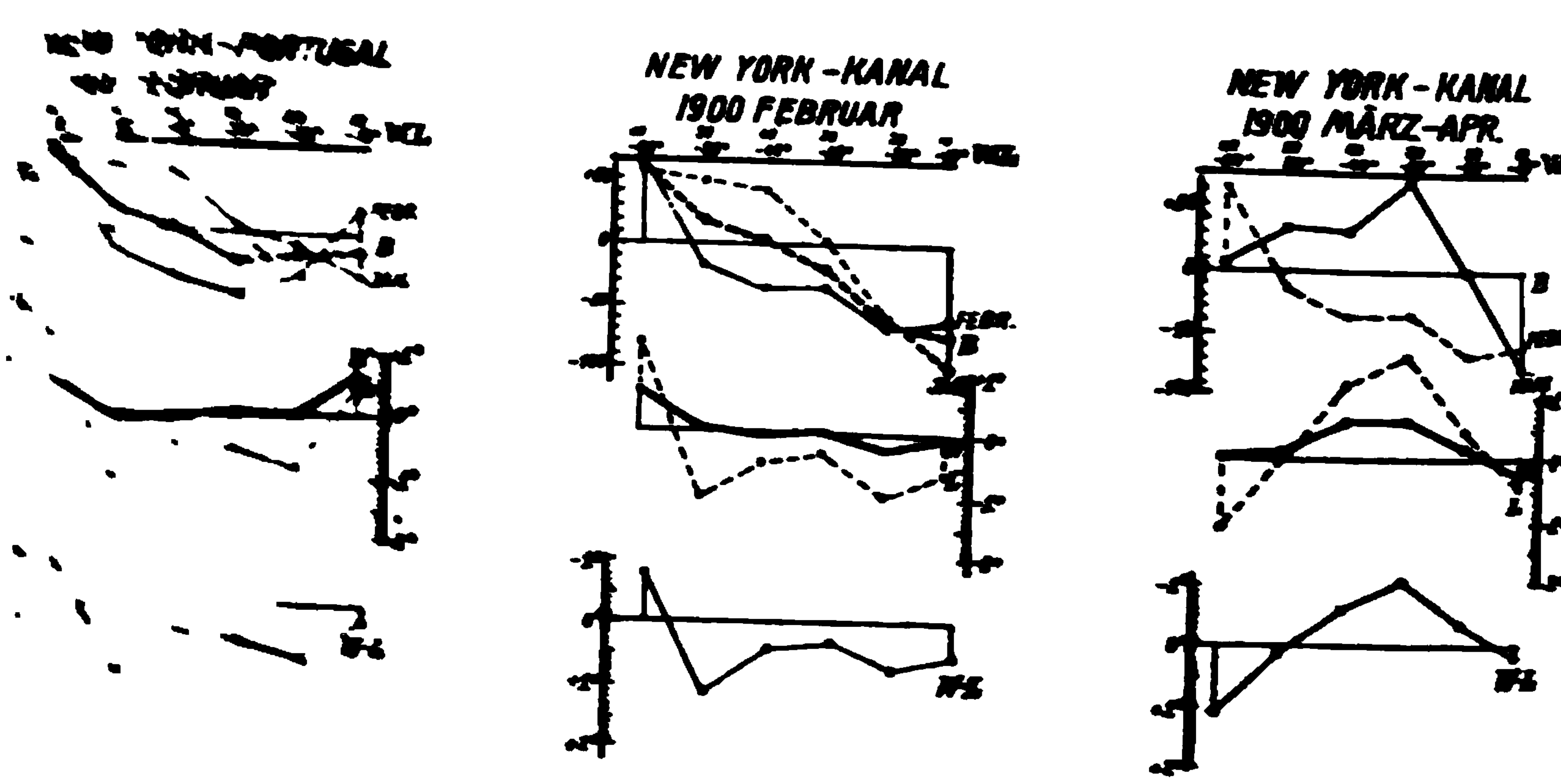


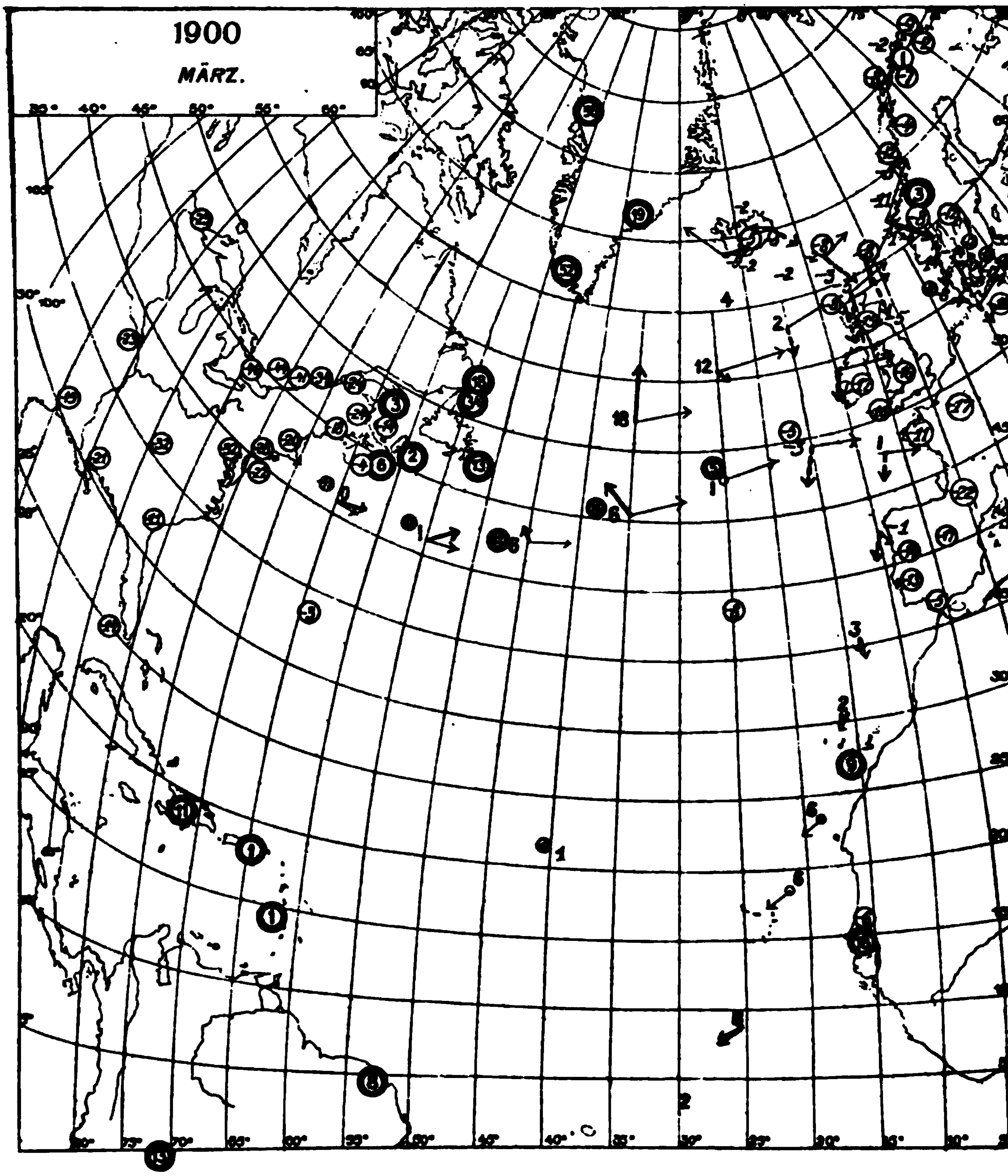


1899

DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	34	24						27	16	7	5	6	1	2	4
II	5	2	15	11	20	18	7	8		11	8	13	4	3	4
III	3	11	5	0	12	24	8	7	3	7	2	5	2	3	1
IV	4			35	15	15	13	5	5	1	4	0	10	1	4
V	20		32			3	7		9	0	3	7	9	7	5
VI	9	26	26	29		5	2	4	0	1	5	5	5	0	2

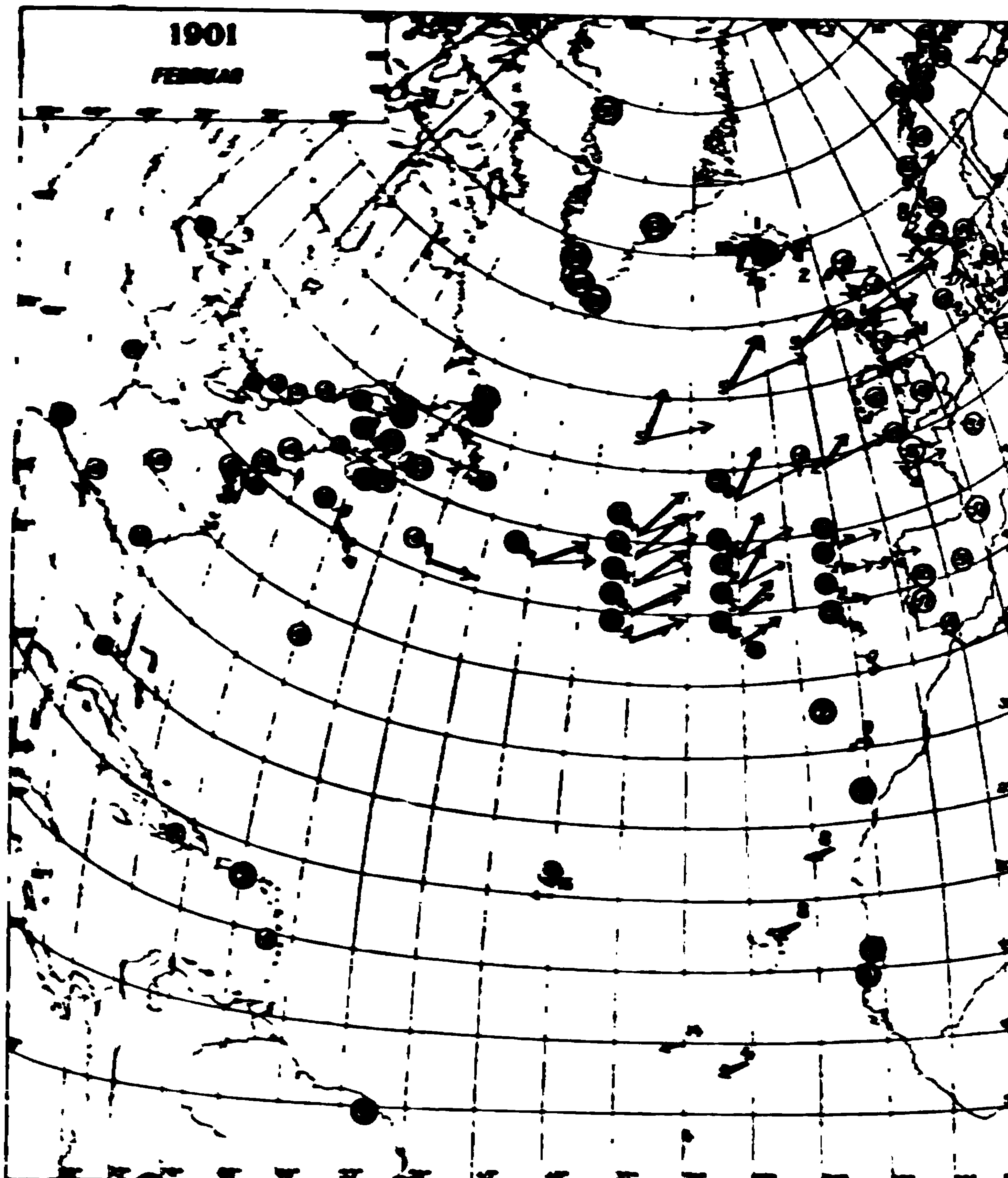

1900
FEBRUAR

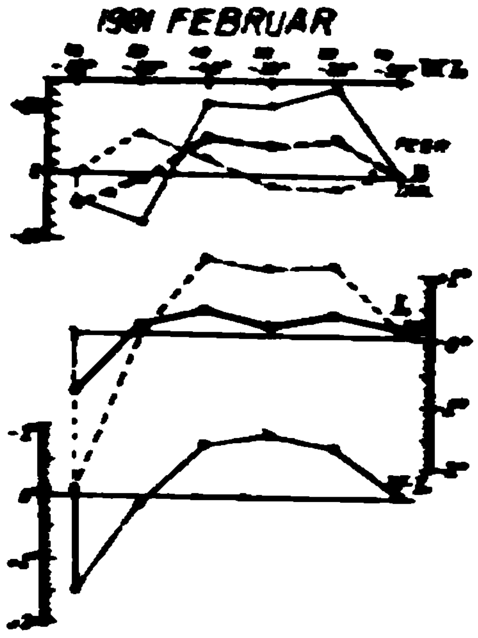

NEW YORK-KANAL
1900 FEBRUAR
NEW YORK-KANAL
1900 MÄRZ-APR.

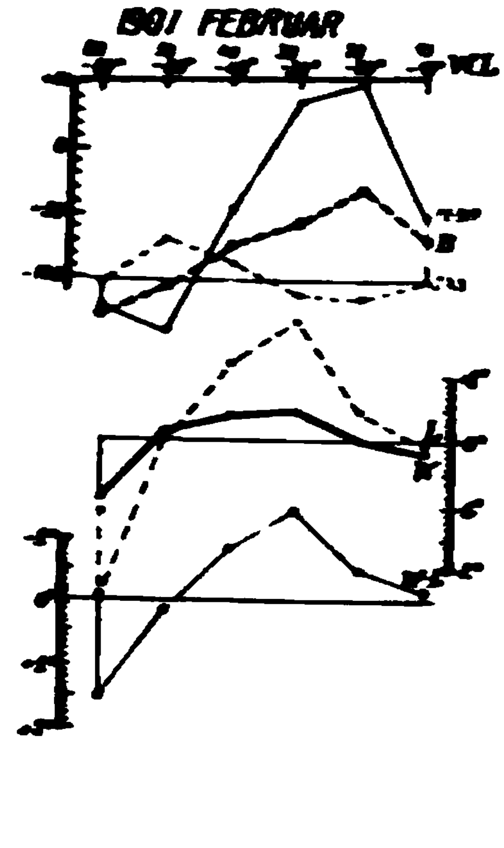


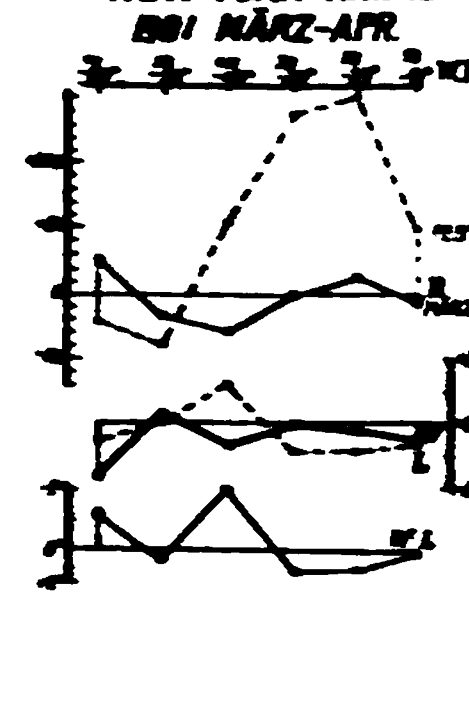
1900

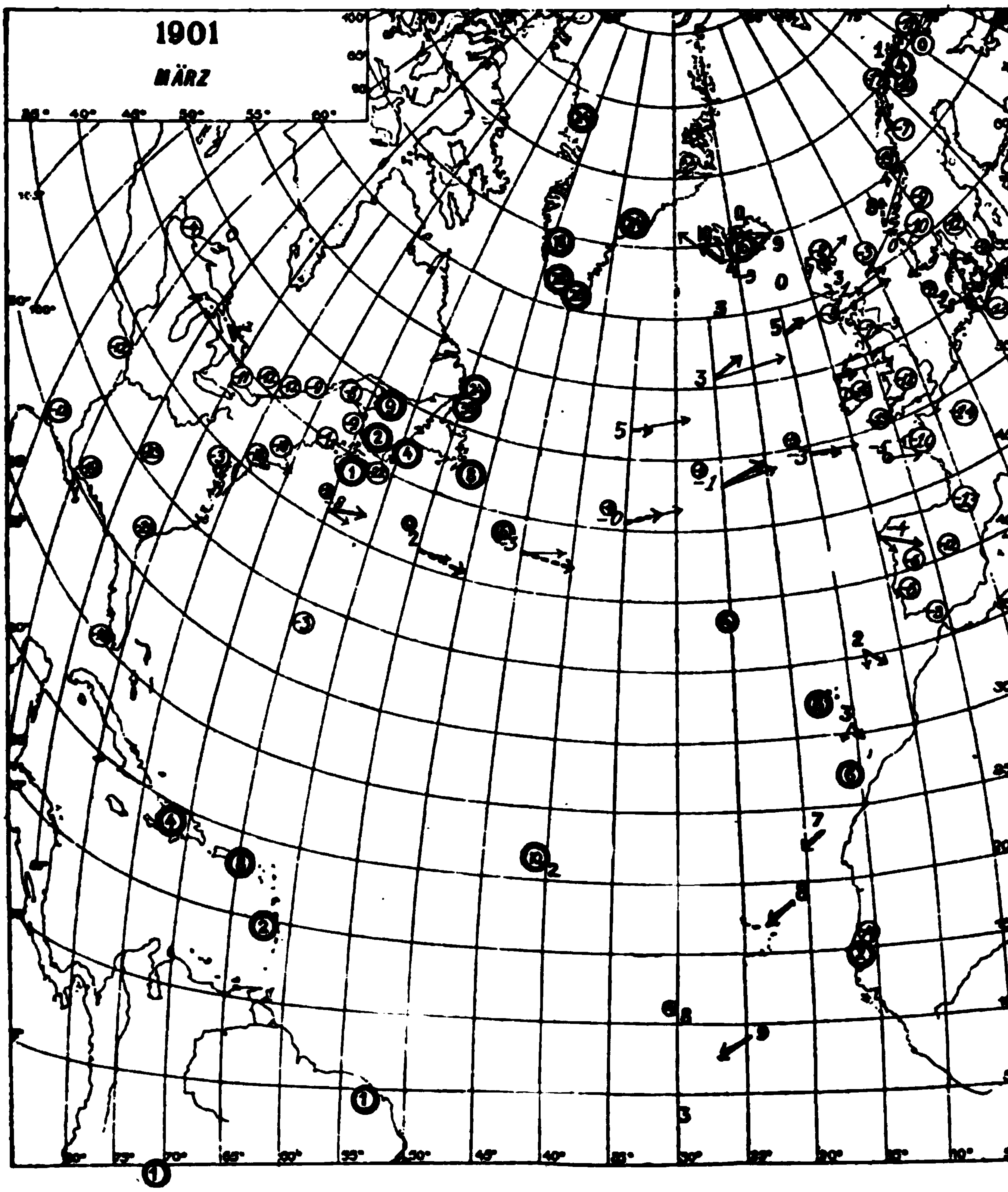
DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	7	23	10	8	10	7	0	2	3	4	6	2	3	3	0
II	32	9	9	6	12	4	12	3	3	6	5	2	2	0	1
III	16	5	9	3	17	9	7	3	3	2	2	4	1	1	1
IV	48	15	11	18	0	0	9	10	7	3	5	3	4	5	0
V	6	16	5	5	6	9	7	8	5	11	10	8	6	0	3
VI	10	7	11	10	14	1	2	6	3	8	8	4	11	1	1


1901
FEBRUAR


NEW YORK-PORTUGAL
1901 FEBRUAR

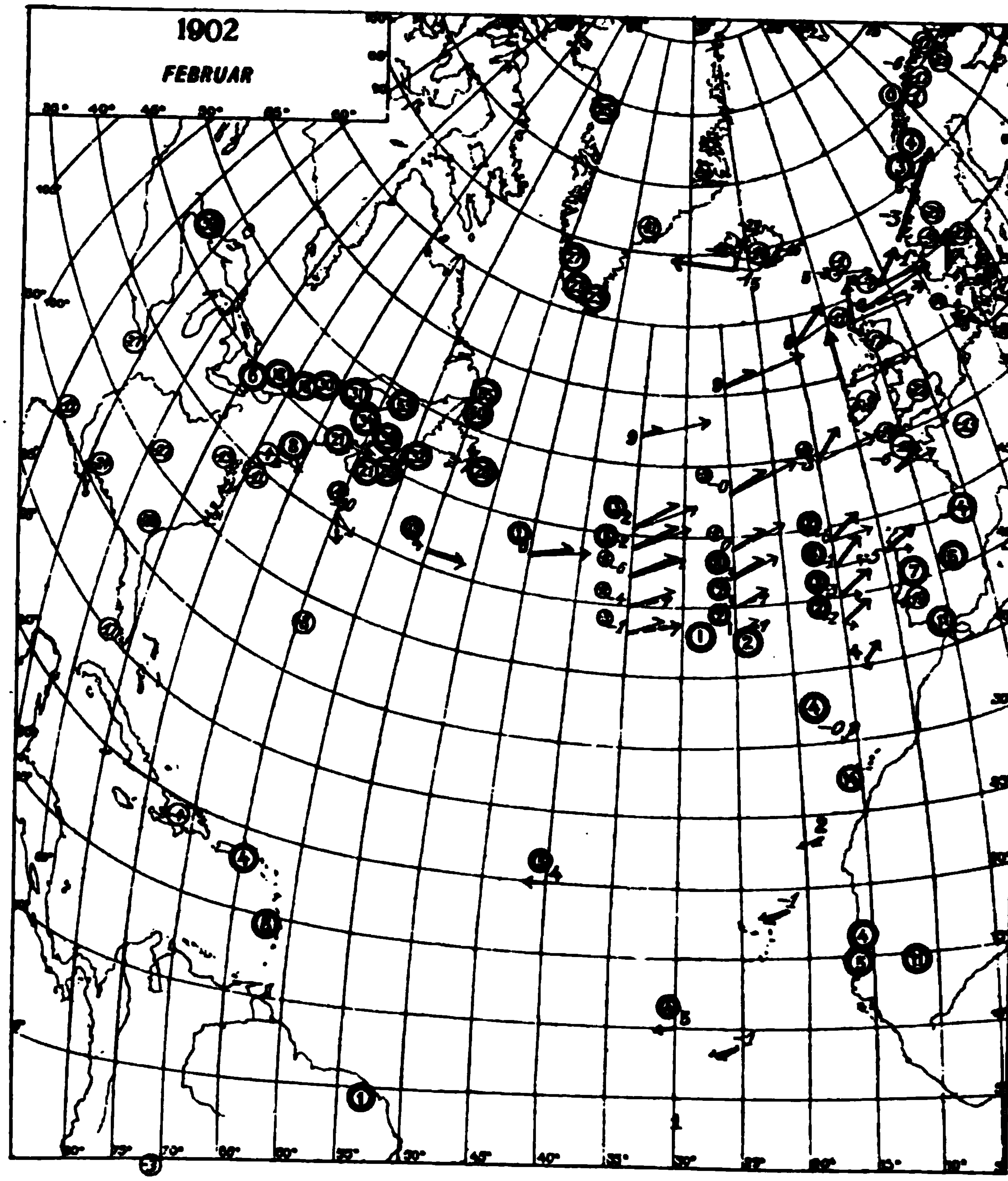

NEW YORK-KANAL
1901 FEBRUAR


NEW YORK-KANAL
1901 MÄRZ-APR.



1901

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	21	11	6	4	13	4	0	3	2	2	2	2	3	1	6
II	18	15	8	7	6	0	9	12	9	4	4	2	2	3	5
III	10	15	2	3	6	1	2	7	4	4	5	2	3	2	4
I	6	28	4	3	9	19	4	1	2	0	4	0	2	2	9
II	11	21	6	7	9	22	19	2	2	4	3	0	1	8	7
III	7	0	1	7	25	15	3	2	2	3	5	3	4	3	2



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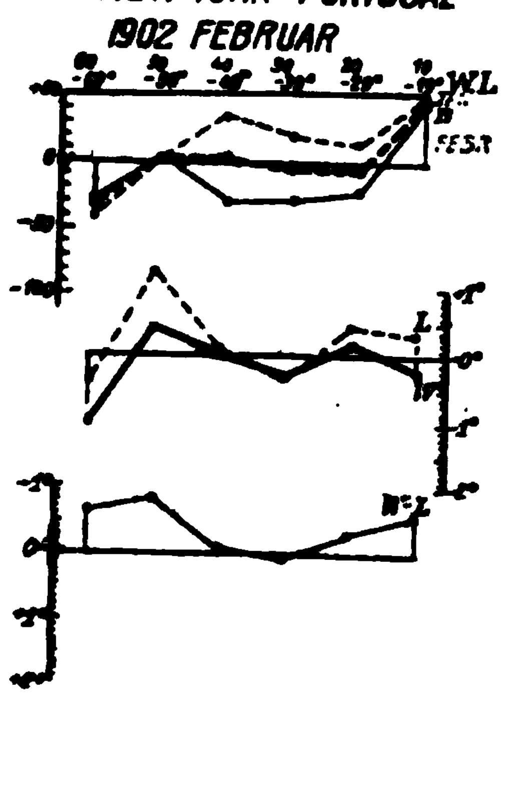

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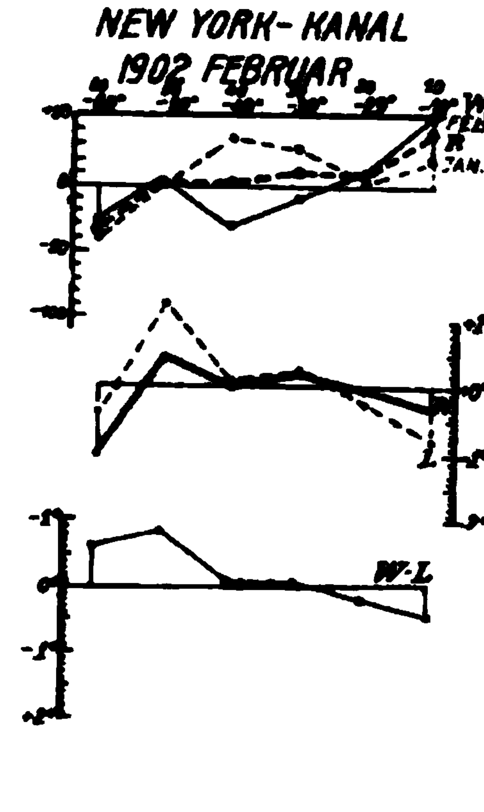
1902 FEBRUAR



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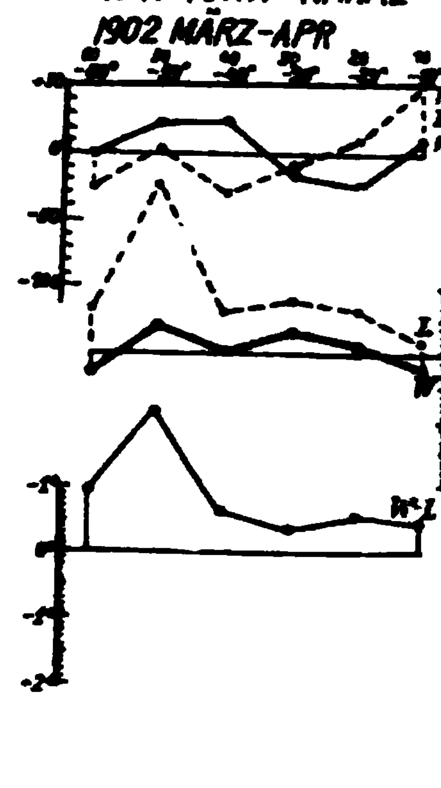
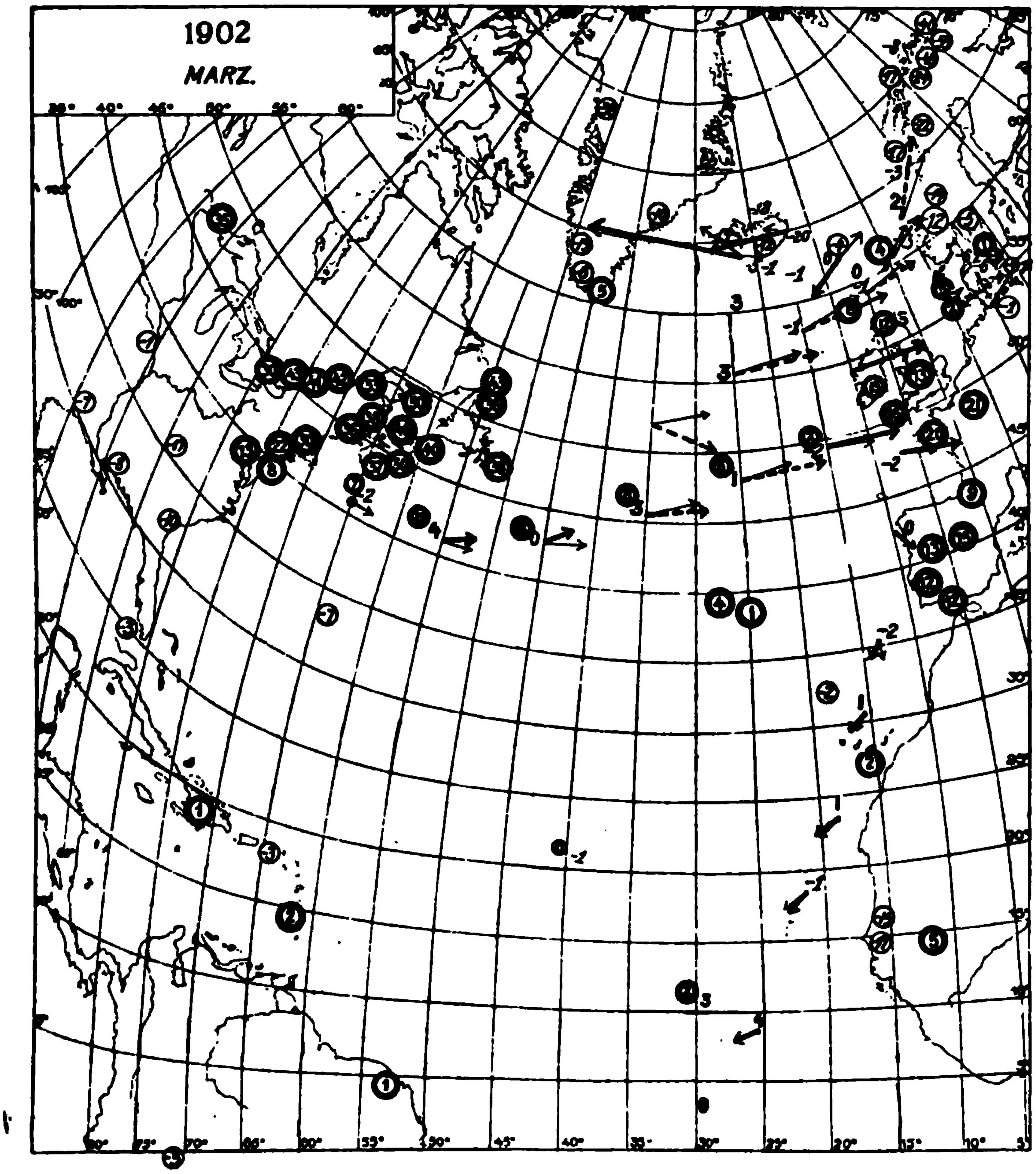
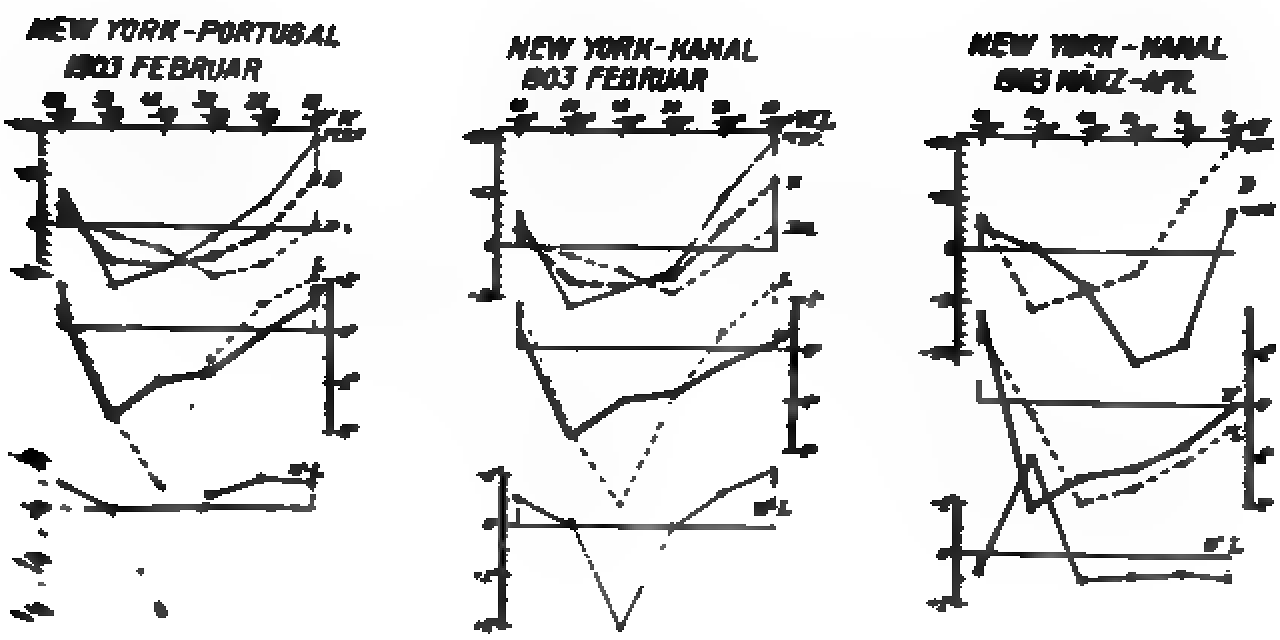
1902 MÄRZ-APR





1902

DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	9	26	13	7	14	1	6	10	7	1	5	2	5	2	9
II	16	7	3	11	19	10	2	1	0	5	5	6	5	3	5
III	7	4	5	7	22	1	2	2	1	6	2	1	1	0	2
IV	5	8	5	12	14	3	2	5	5	0	2	3	4		1
V	9	12	7	18	16	5	3	6	5	9	1	5	2	0	0
VI	15	17	2	3	15	8	1	2	3	2	1	1	4	3	3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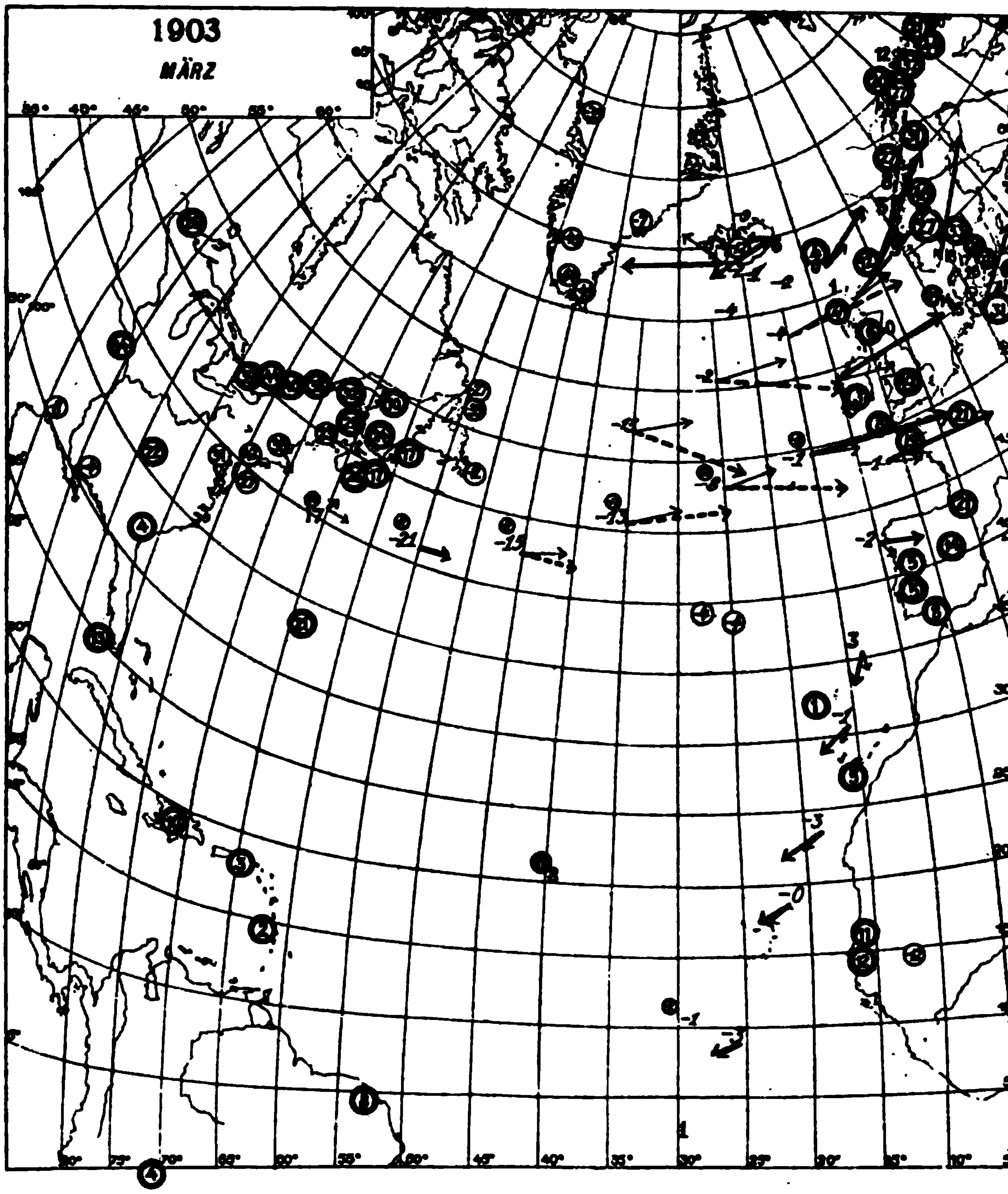
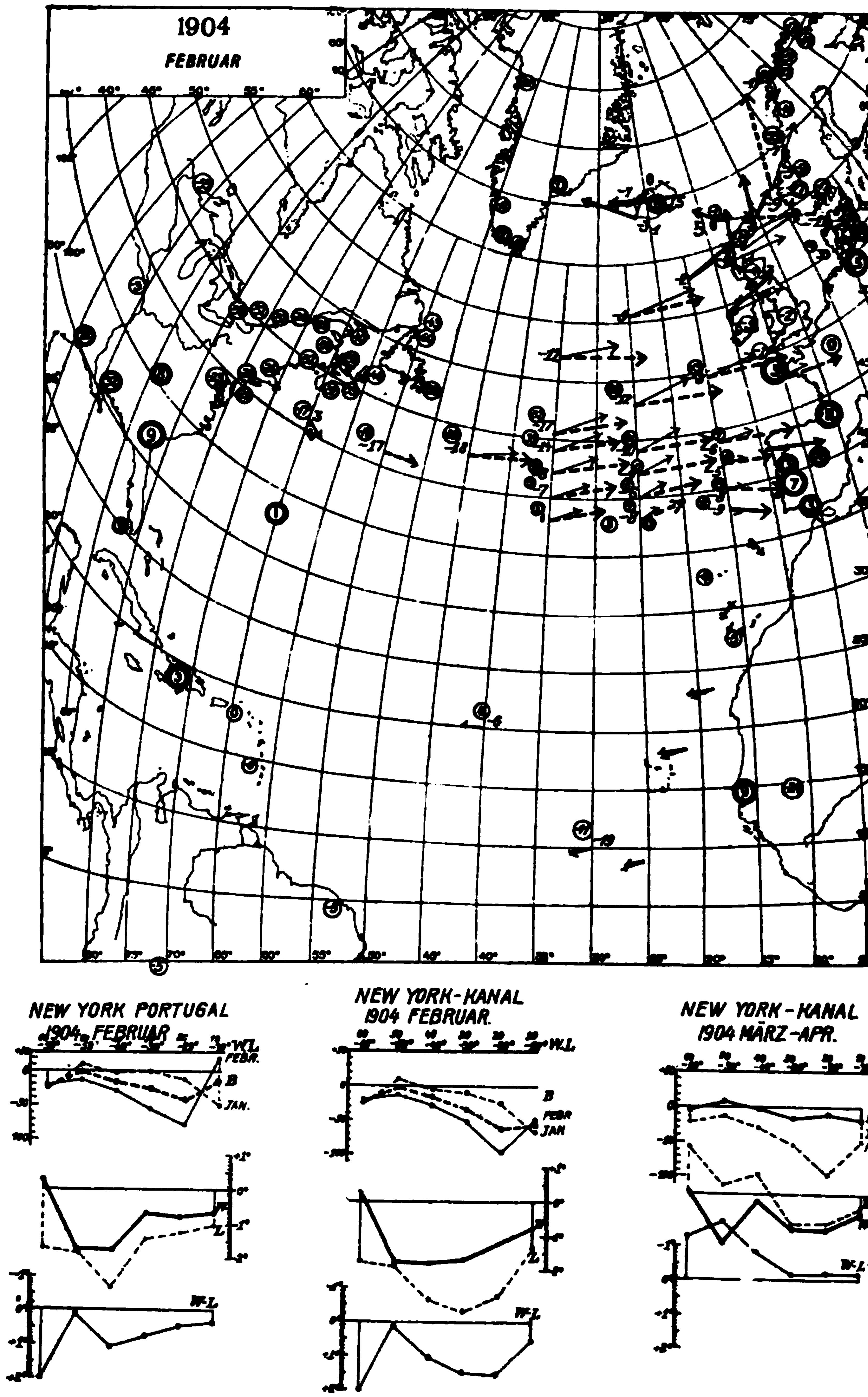
1903 MÄRZ-APR.



1903

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	4	15	6	15	29	17	19	11	7	9	5	1	0	0	2
II	6	2	11	4	13	6	16	12	8	7	2	1	5	5	5
III	6	16	13	12	21	26	22	17	11	7	10	5	4	0	1
IV	6	23	16	3	41	3	18	11	16	13	11	8	8	7	2
V	35	16	5	22	31	20	14	18	13	15	,2	10	3	5	5
VI	28	1	5	21	33	16	16	7	8	11	9	5	3	0	0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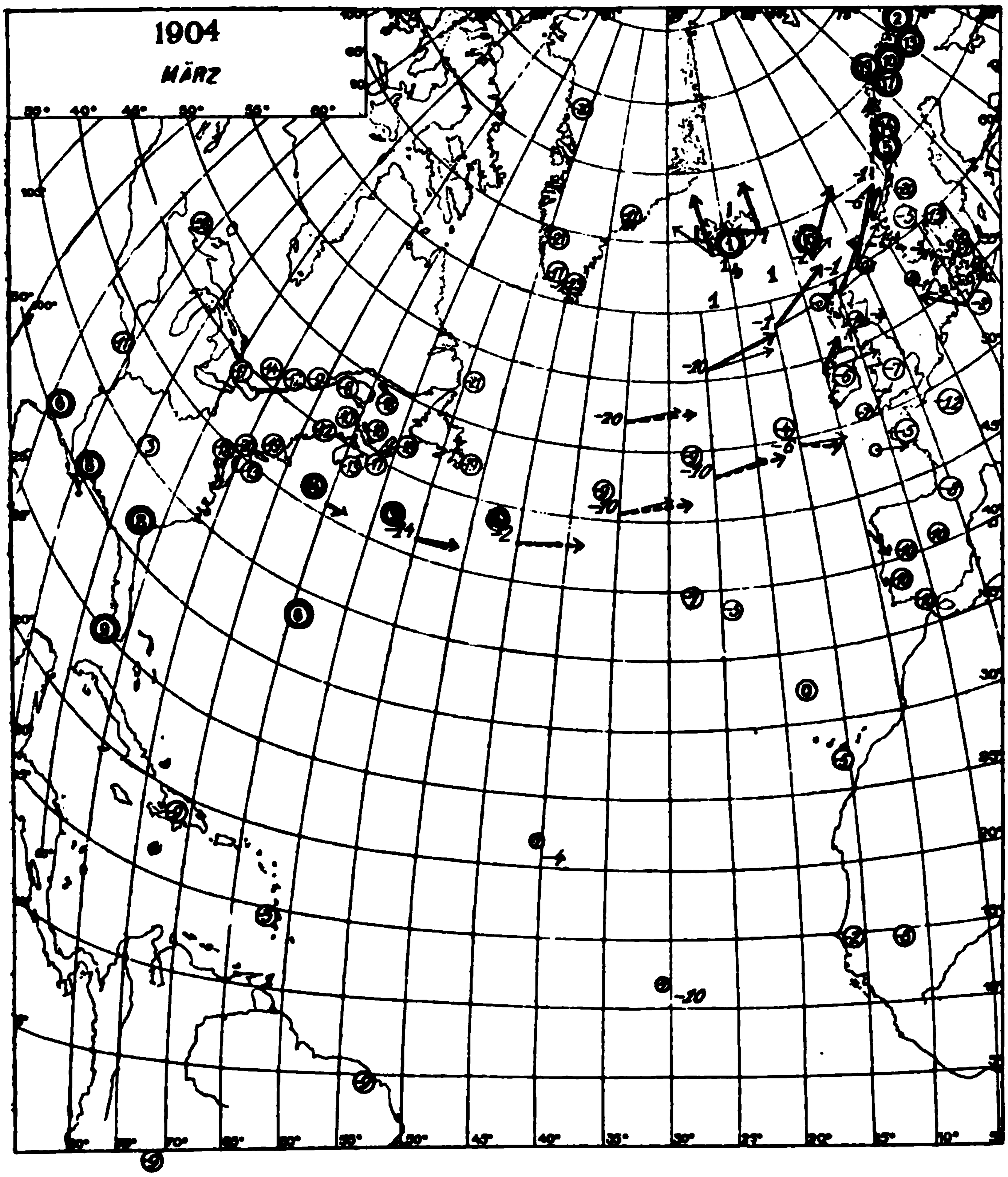
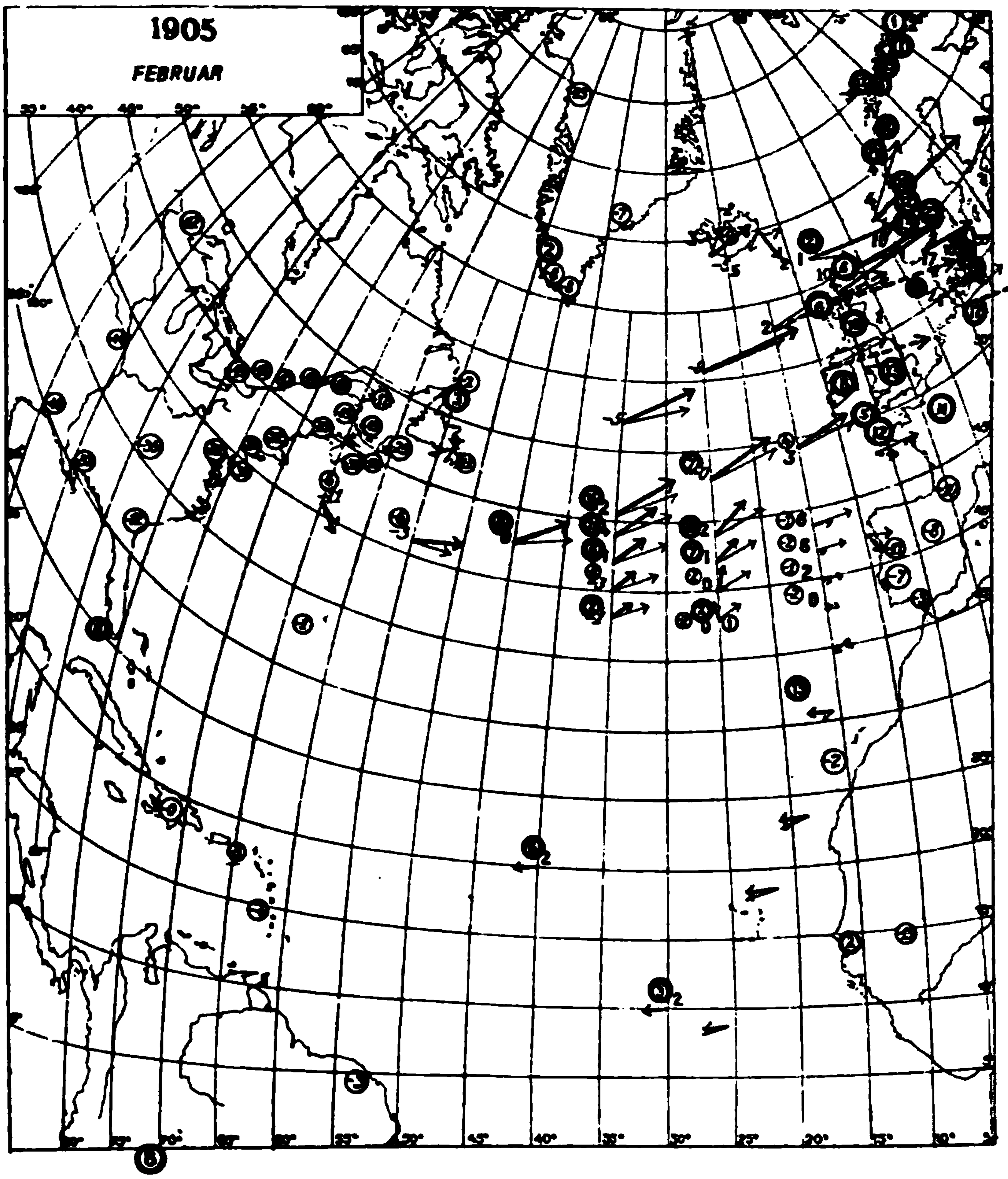


1904

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	7	4	8	1	8	20	2	22	13	17	12	23	14	14	10
II	17	4	17	25	19	22	20	15	10	15	14	14	11	8	5
III	14	25	31	35	22	8	11	10	23	19	10	3	5	6	2
I	24	5	10	36	4	4	9	18	7	15	8	6	4	2	2
II	18	20	24	14	0	7	1	12	13	15	13	14	12	6	7
III	11	17	4	18	1	7	5	11	6	8	11	10	9	10	5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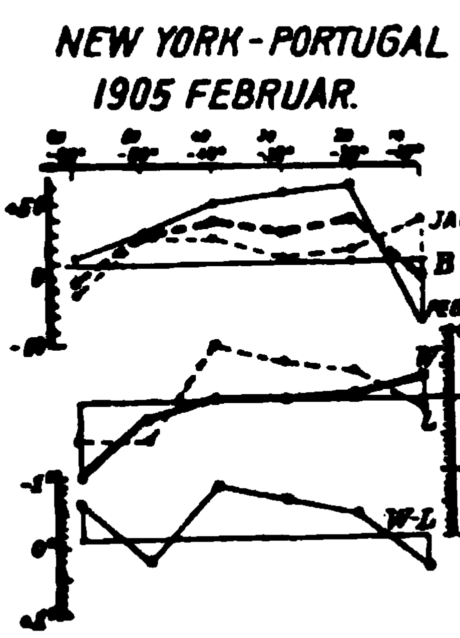
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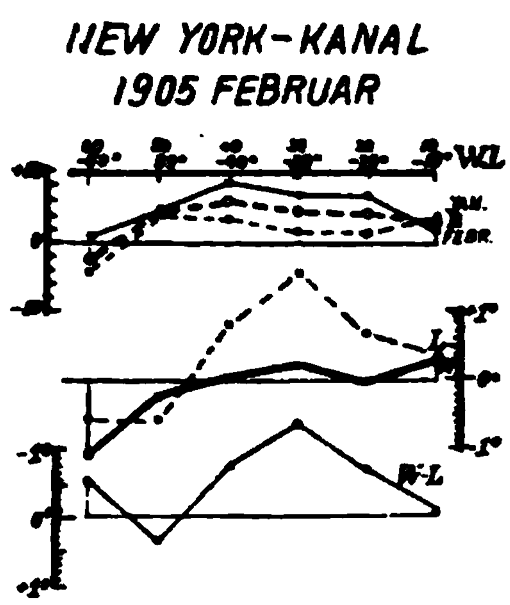
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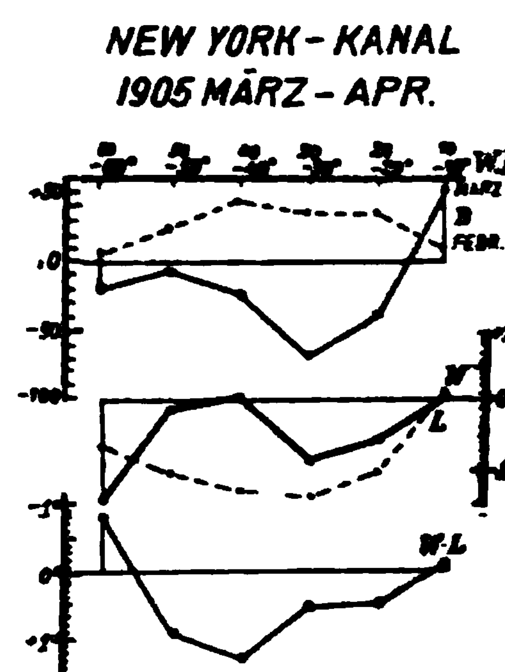
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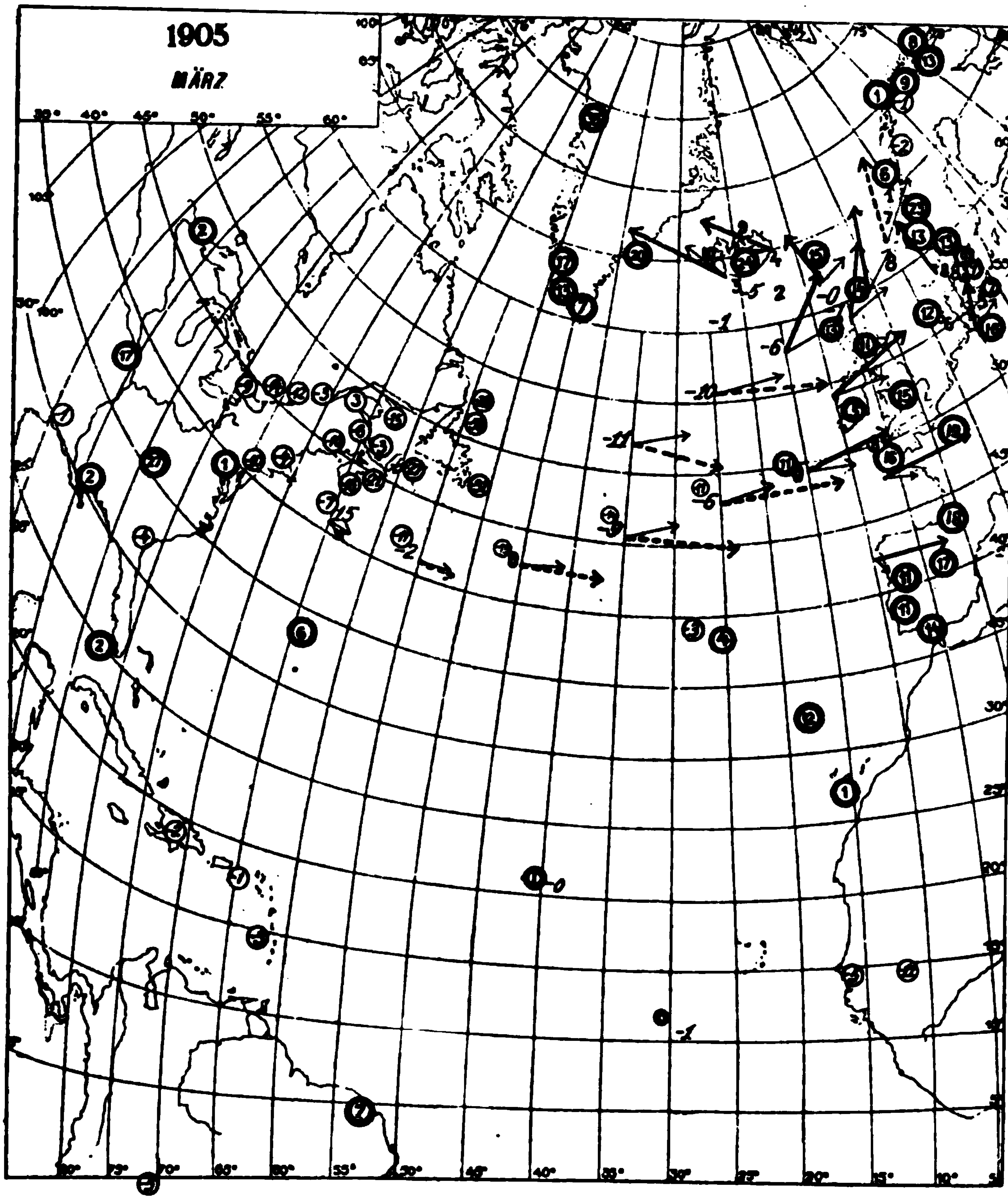
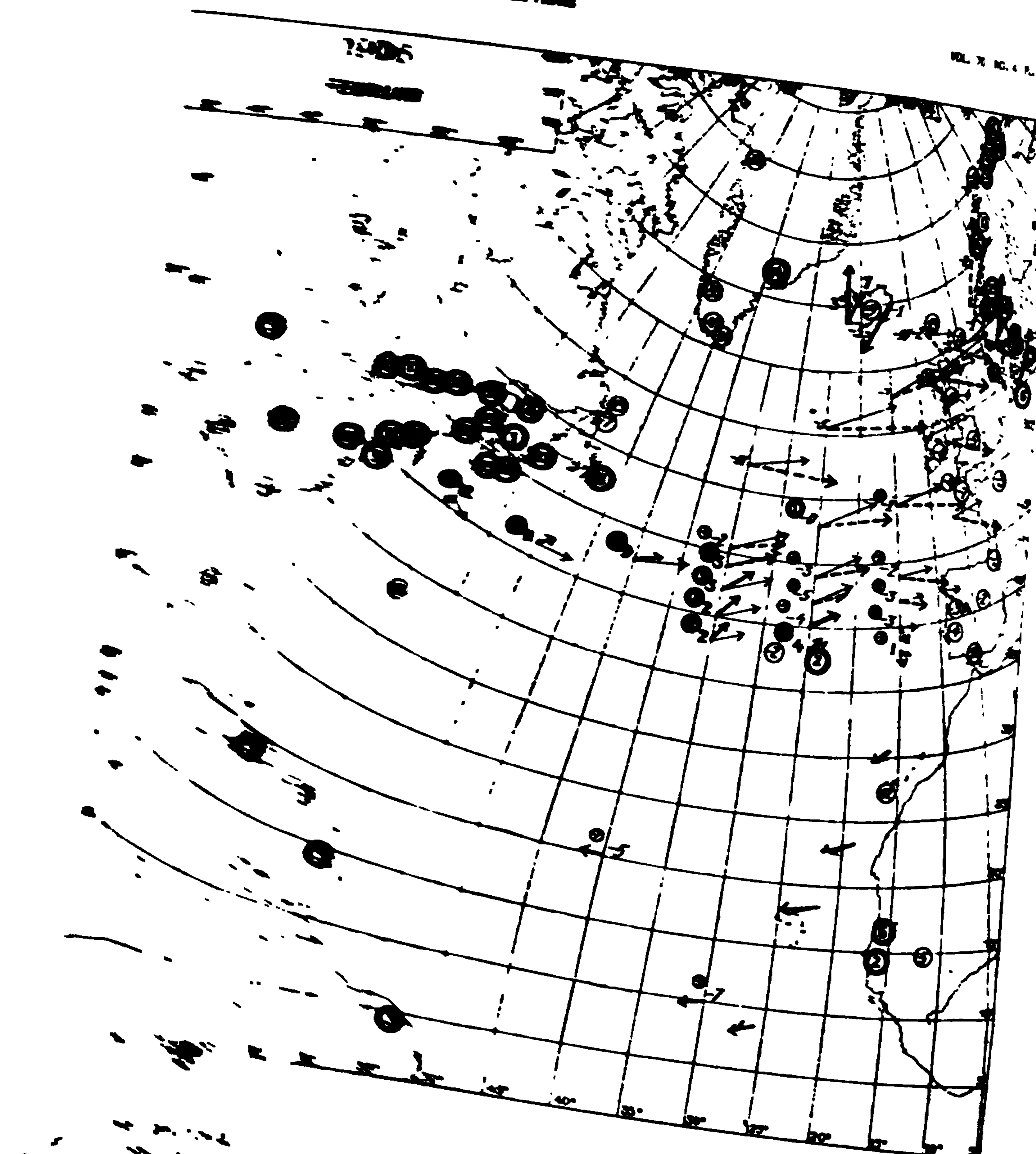


1905

DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	7	9	2	5	6	5	1	3	2	2	0	4	9	7	5
II	6	9	1	1	17	5	8	3	1	3	0	0	4	2	3
III	6	18	1	8	3	13	8	10	5	1	1	3	1	0	3
I	14	20	11	7	8	0	6	9	15	11	8	12	5	3	1
II	0	15	1	2	7	7	2	2	7	9	8	7	1	0	1
III	8	26	16	1	9	17	3	0	3	0	3	2	3	4	5



45°
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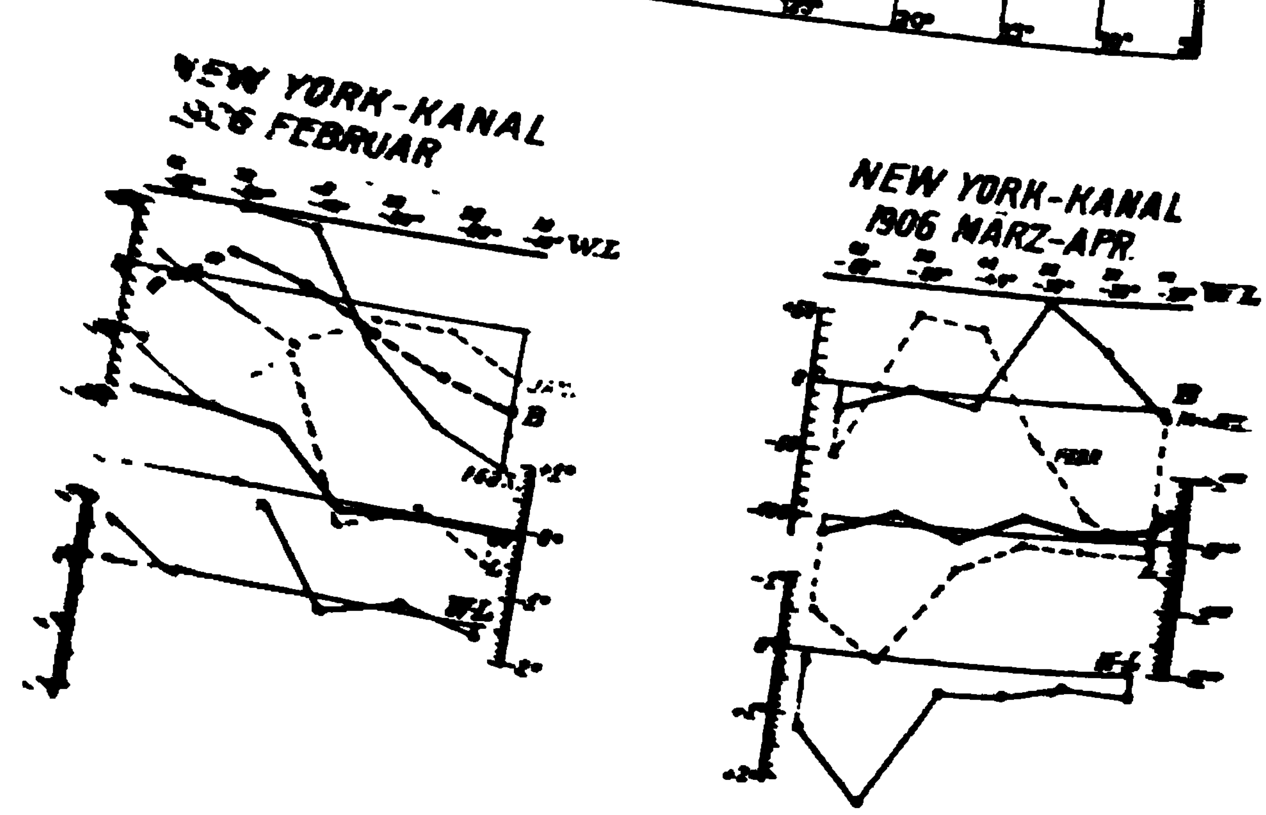
20°
15°
10°



NEW YORK-KANAL
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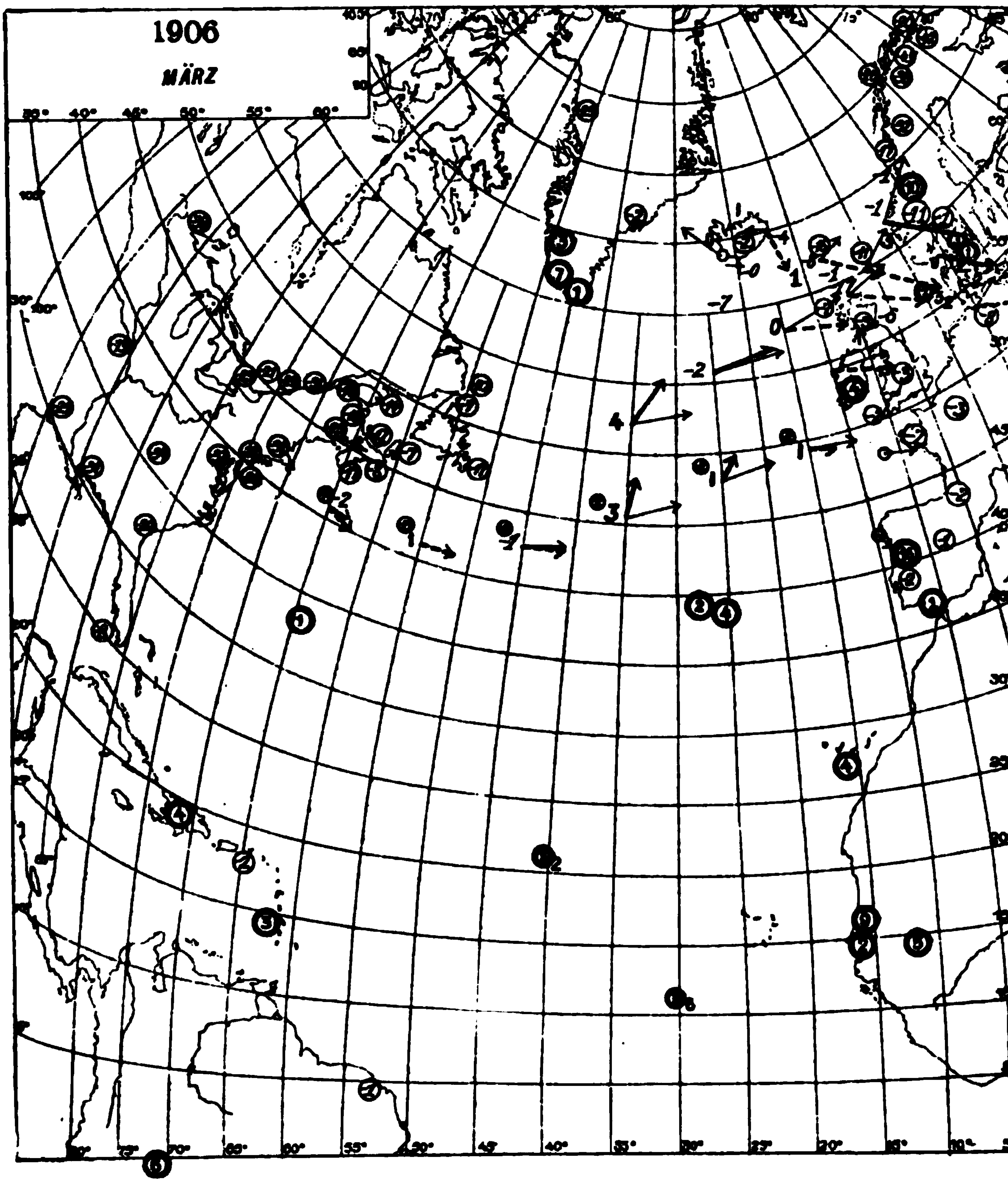
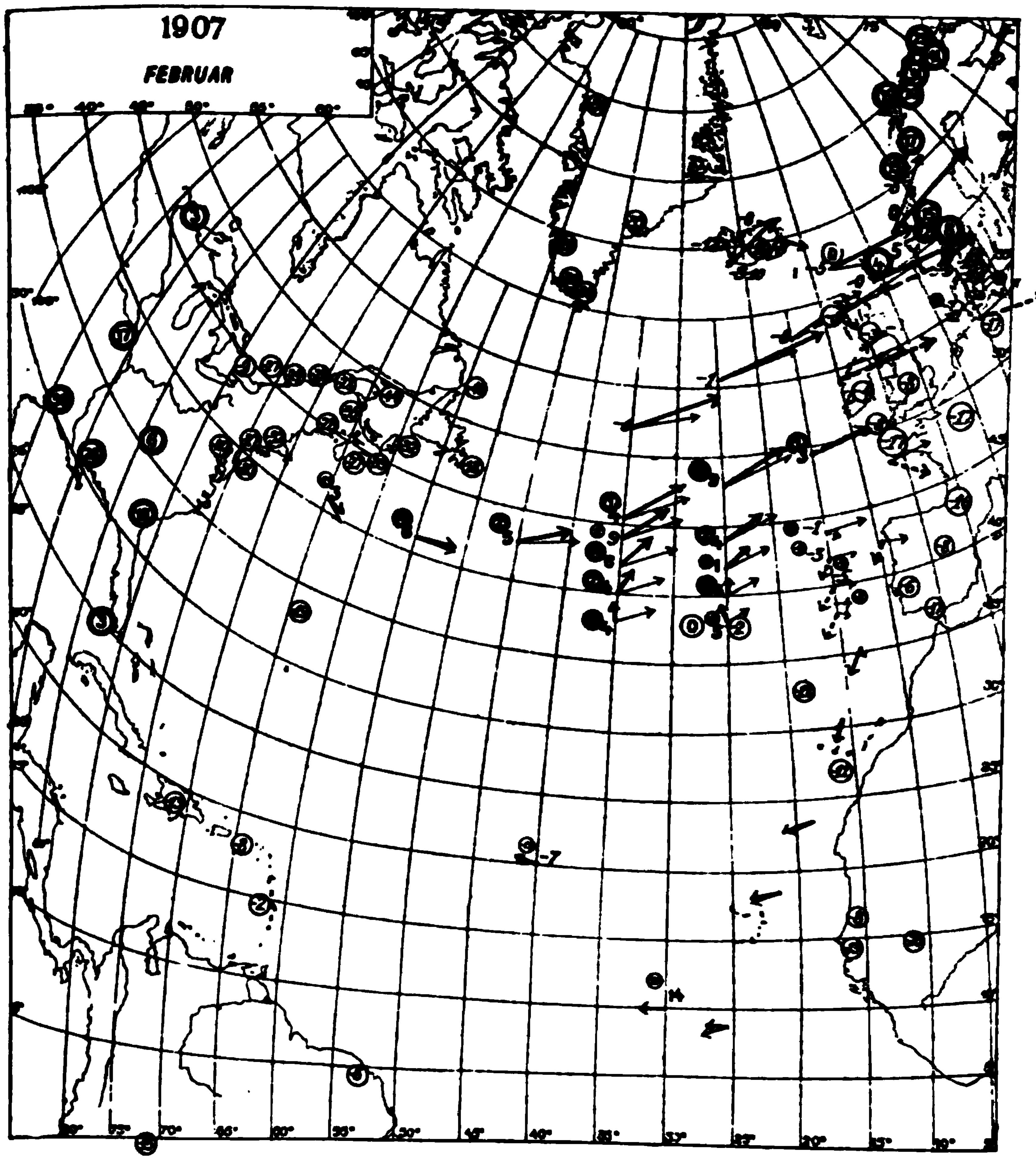
NEW YORK-KANAL
1906 MÄRZ-APR.
W.L.



1906

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	26	7	17	2	10	10	17	10	2	0	0	4	1	5	5
II	18	8	14	9	2	8	8	6	7	13	5	5	3	5	4
III	19	3	22	16	14	12	14	4	5	3	1	2	0	0	2
I	8	10	6	8	3	5	8	3	2	2	2	3	2	3	0
II	5	6	6	2	5	10	0	5	8	3	2	1	3	0	2
III	10	4	3	3	0	15	9	5	2	0	2	1	4	3	2



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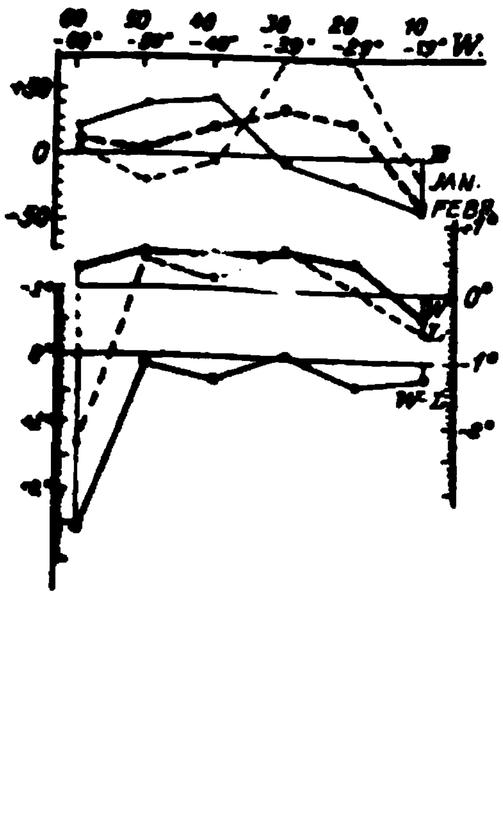

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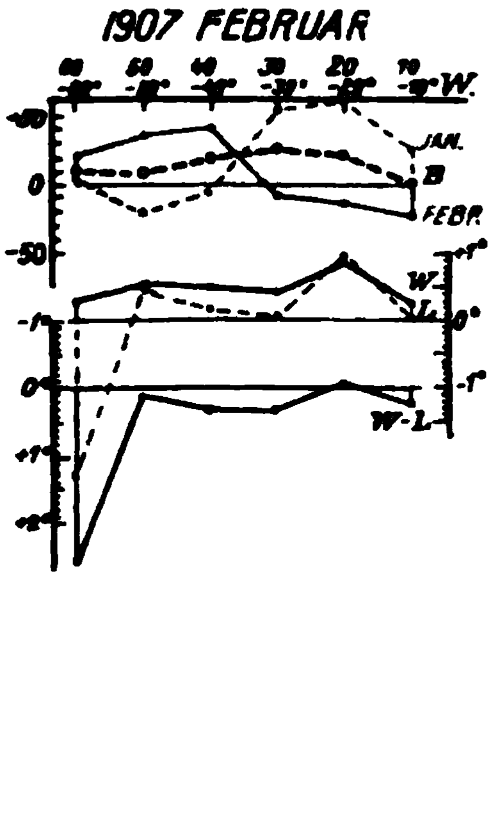
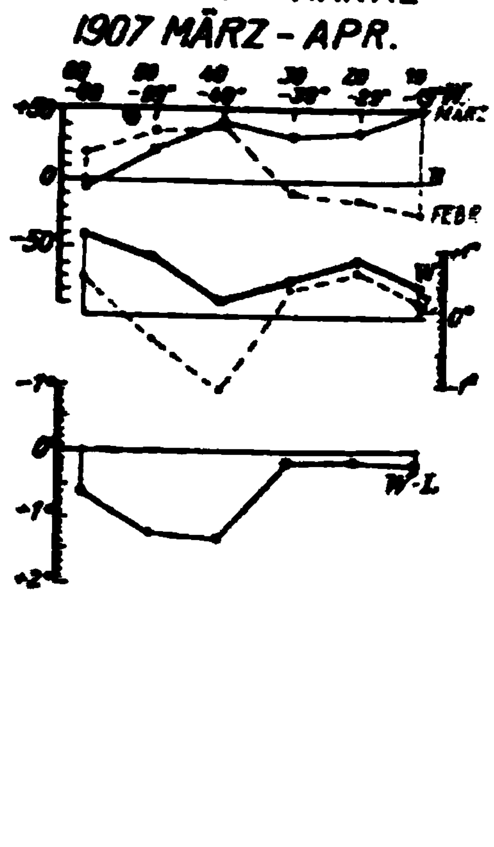
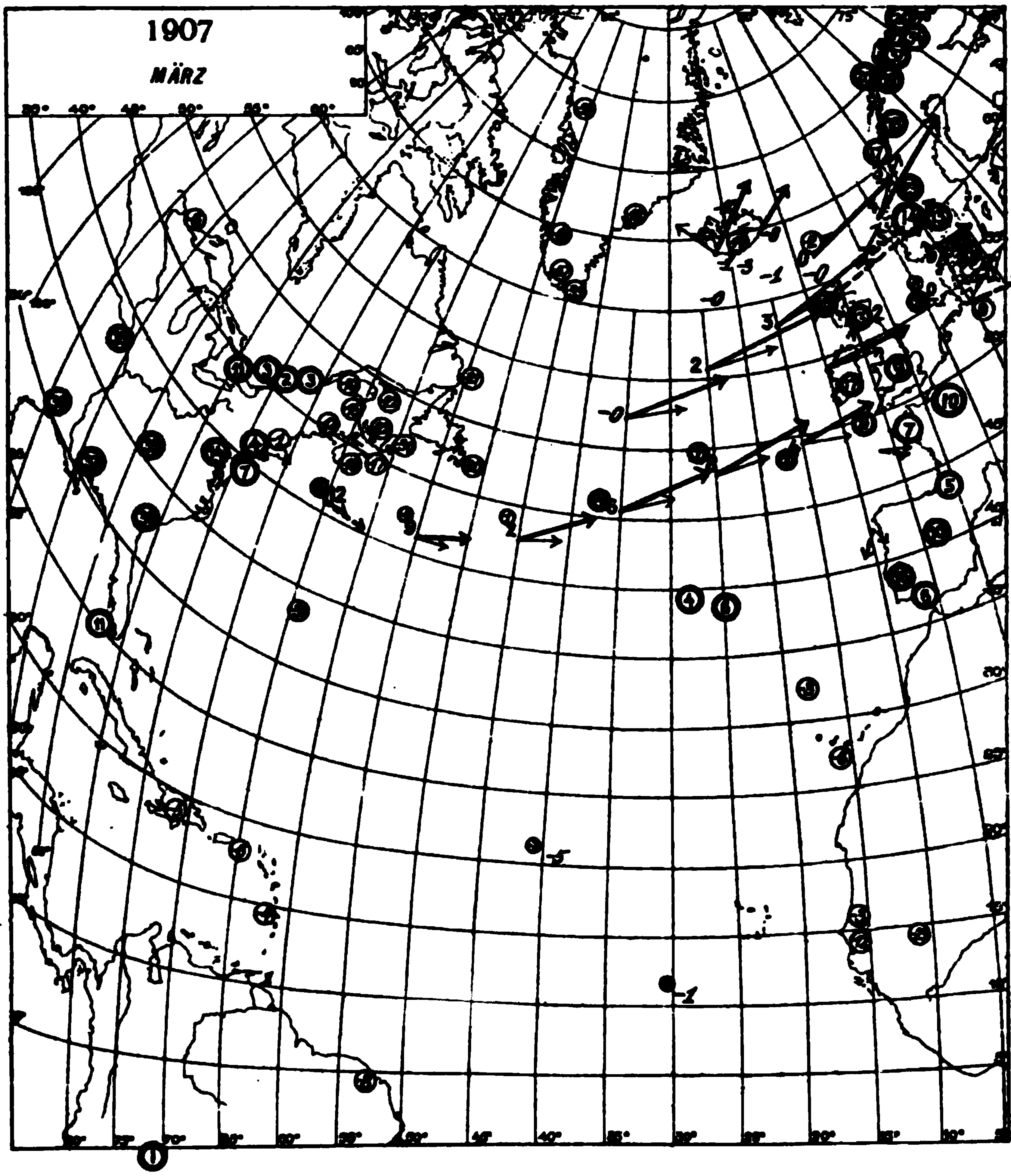
1907 FEBRUAR



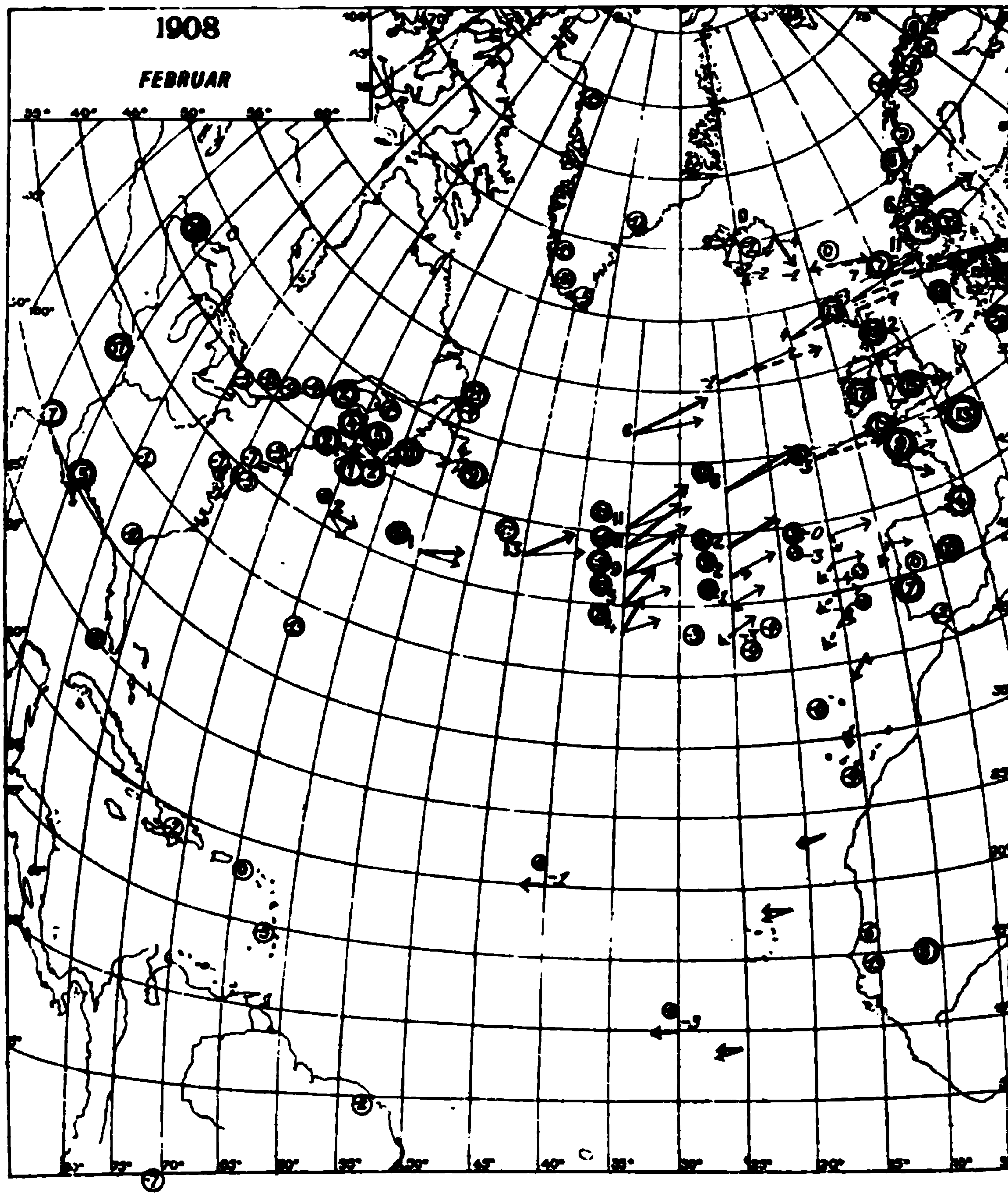
NEW YORK-KANAL
1907 MÄRZ-APR.





1907

Dekade	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	2	5	3	3	20	9	8	2	1	7	10	3	3	2	0
II	4	5	7	4	13	9	12	7	9	7	14	7	8	5	1
III	15	4	10	3	4	12	3	1	1	5	11	10	8	2	2
I	3	5	9	13	3	11	1	5	11	9	12	11	11	6	3
II	5	19	18	25	2	10	11	4	3	1	9	6	2	5	4
III	7	14	30	24	1	18	9	8	6	1	9	8	3	3	2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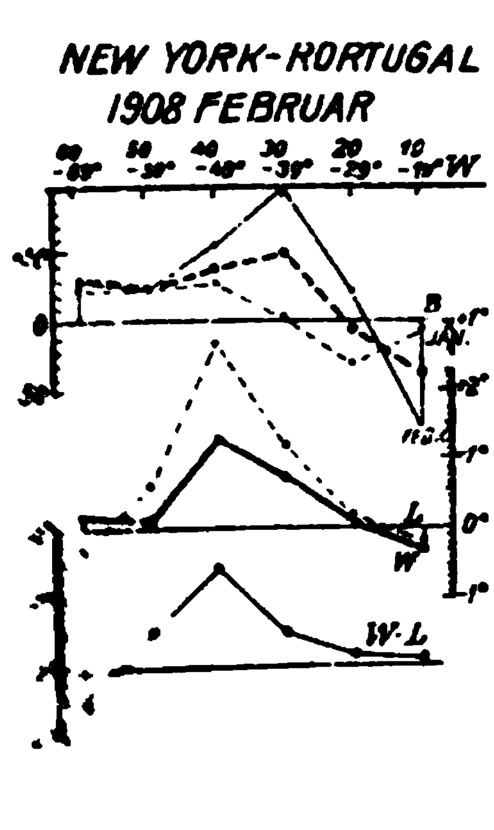
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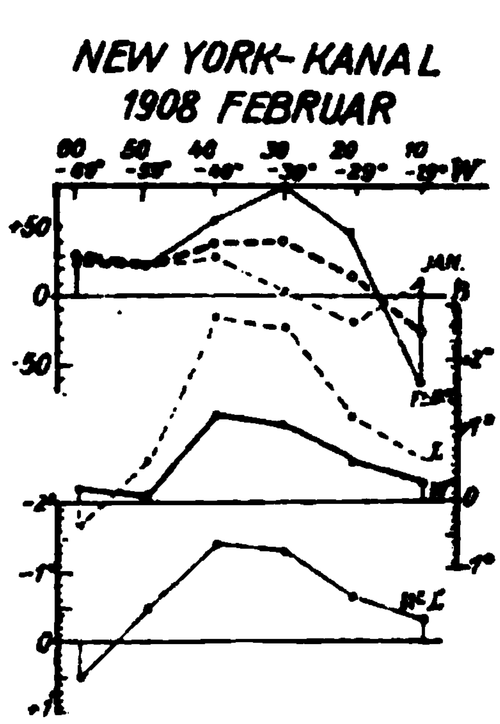
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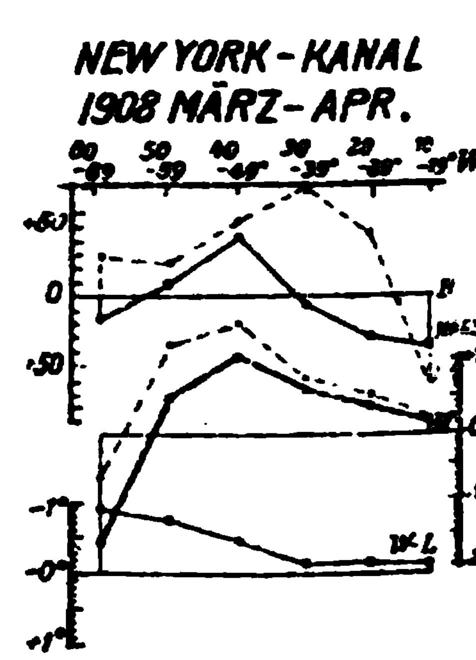
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1908 MÄRZ-APR.
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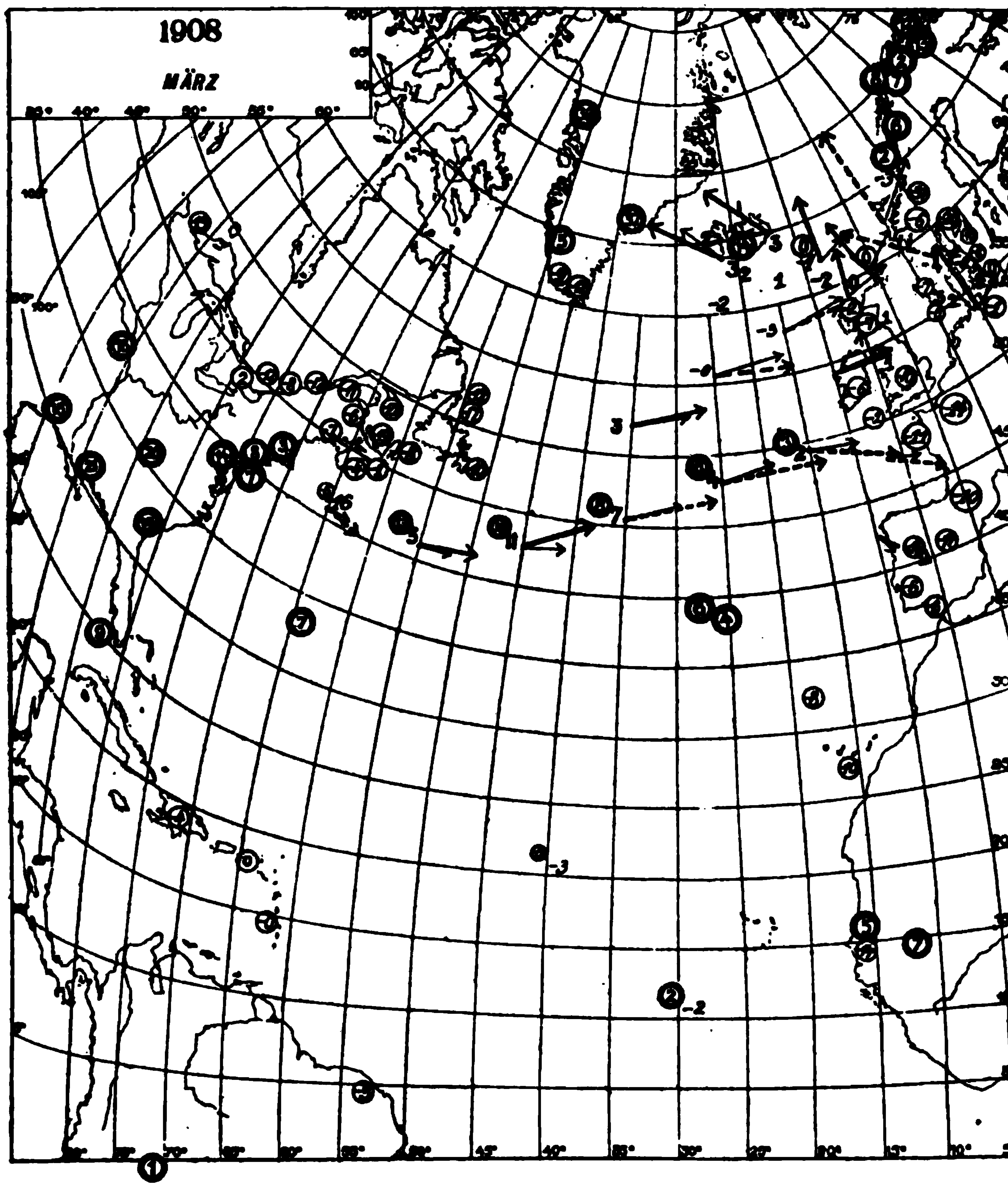
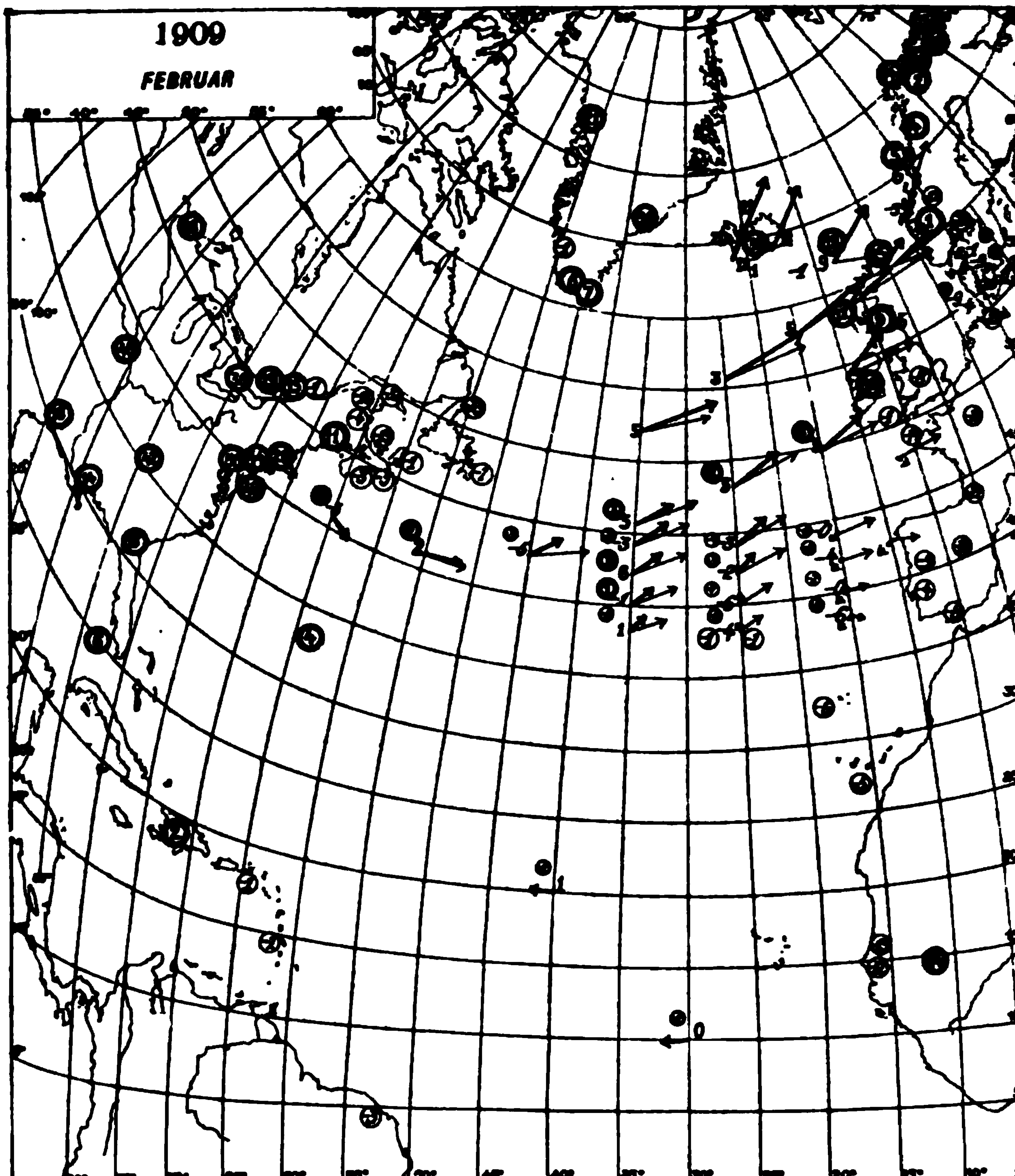


1908

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	6	4	10	2	14	4	3	4	8	11	6	8	6	2	2
II	6	23	9	5	12	14	7	3	10	13	6	3	6	3	5
III	2	24	10	12	4	30	22	12	18	13	6	6	4	3	1
I	0	14	1	15	11	25	9	5	5	13	5	1	0	3	1
II	3	17	19	10	2	19	14	8	6	4	4	3	1	3	3
III	2	26	12	1	6	24	4	7	6	5	4	8	7	2	1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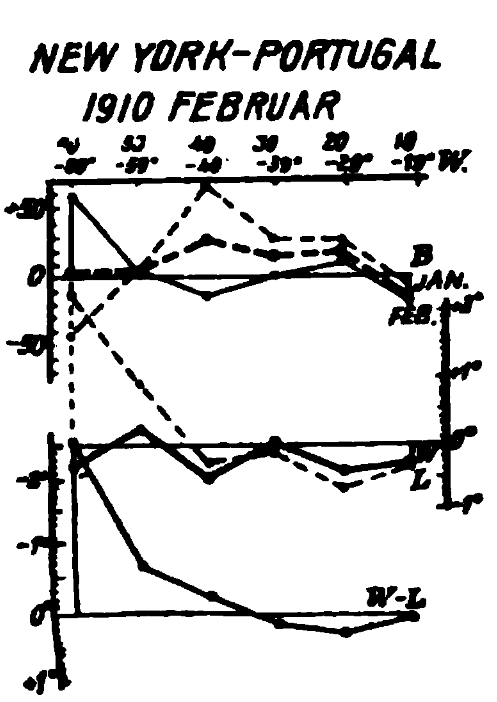
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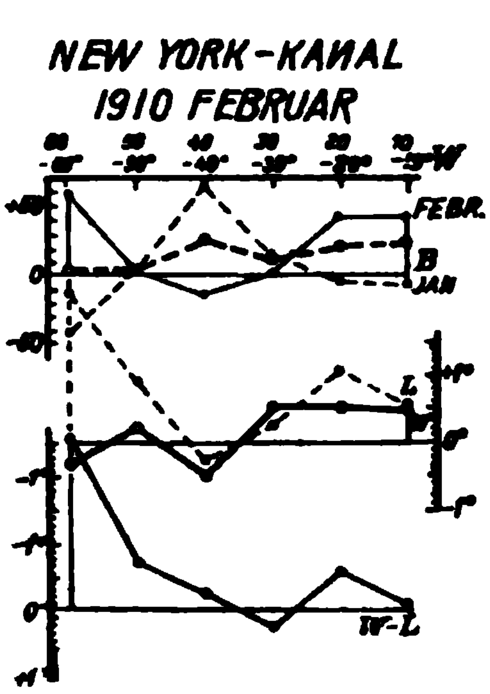
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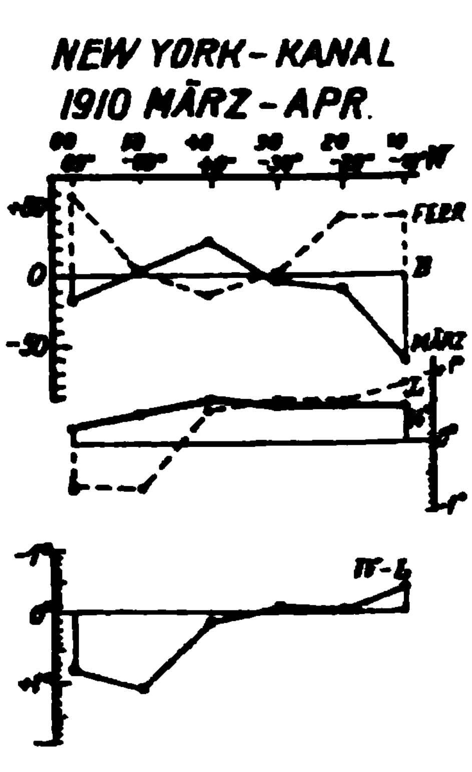
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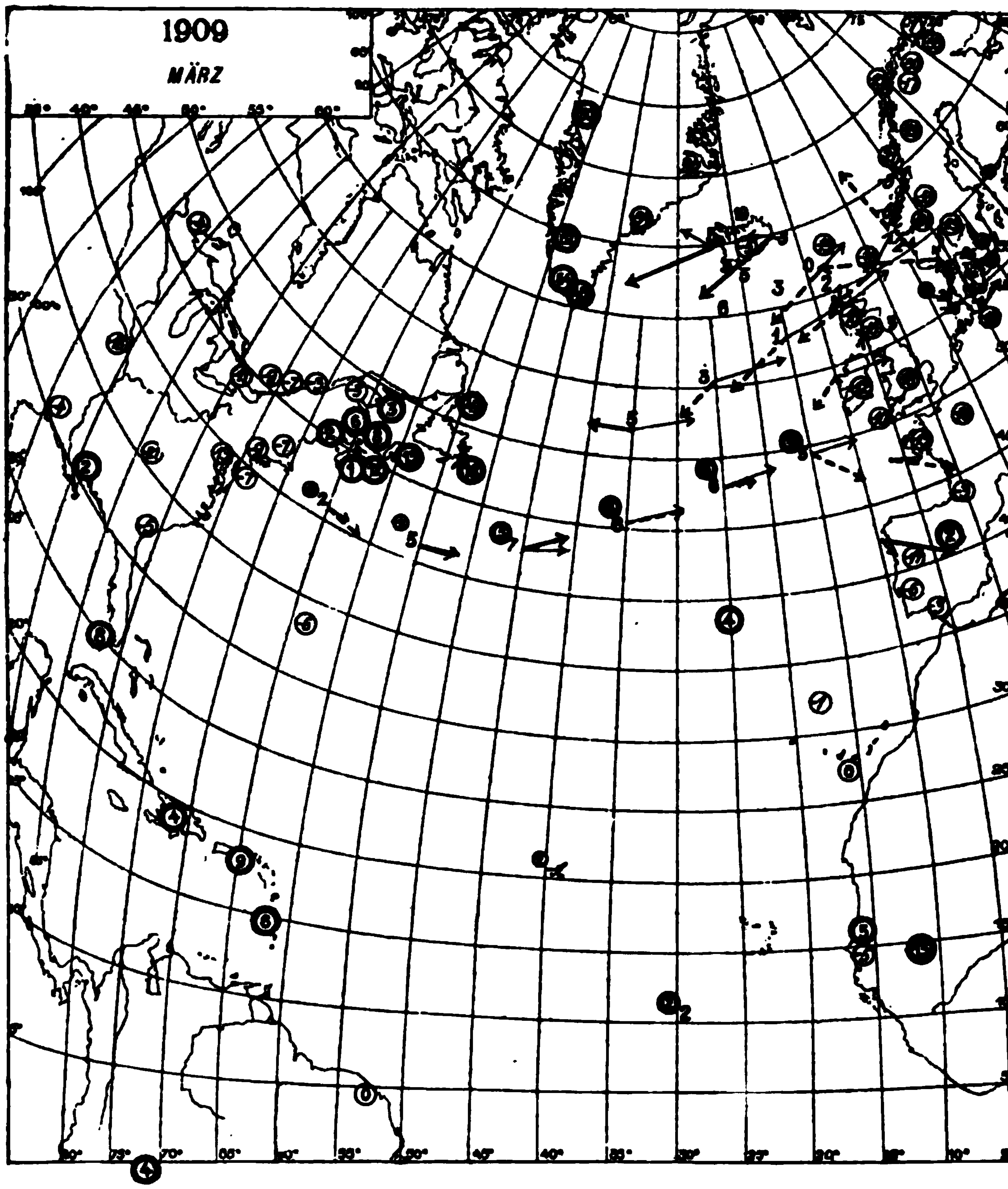
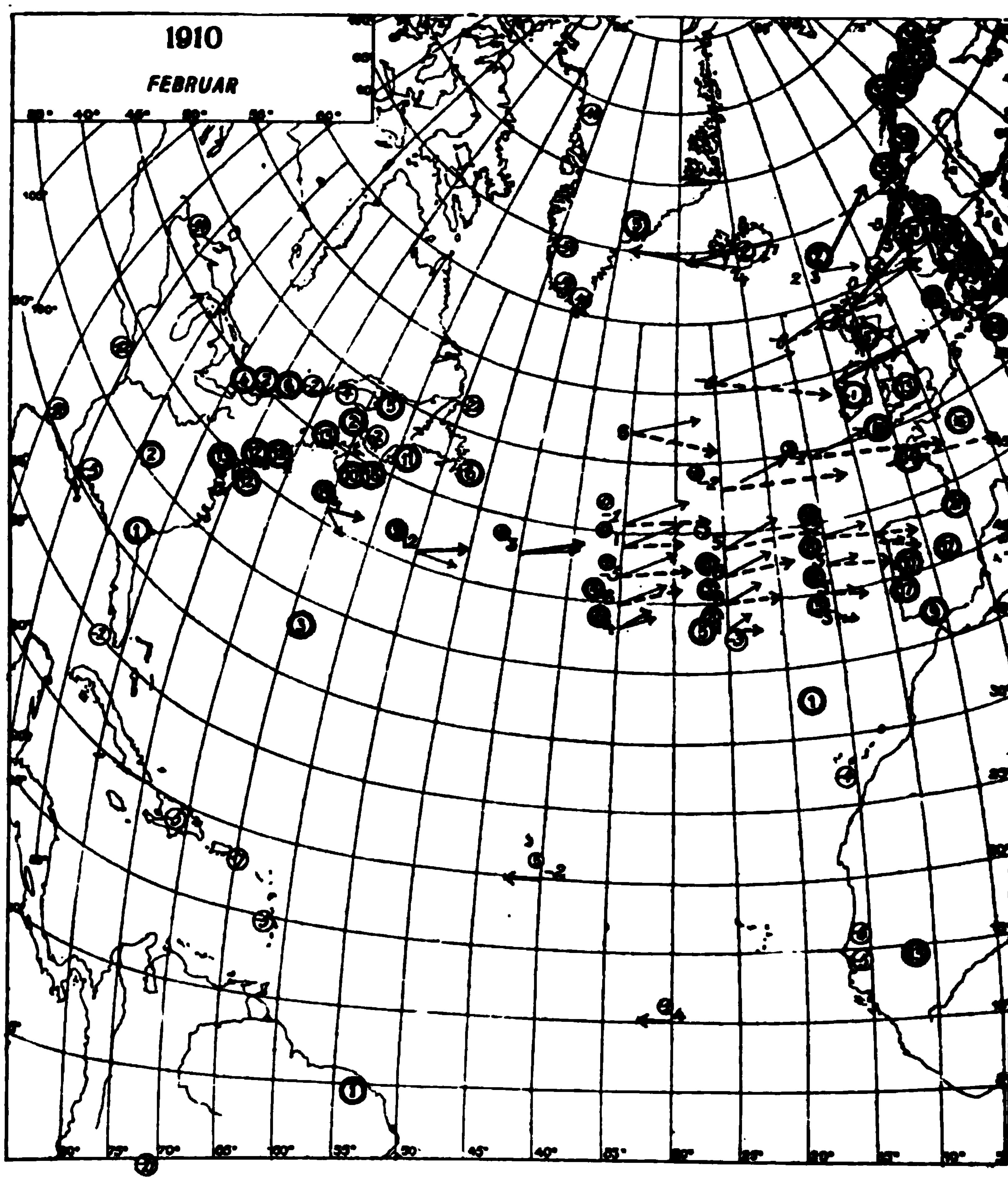


1909

DEKADE	70-66°	66-62°	62-58°	58-54°	54-50°	50-46°	46-42°	42-38°	38-34°	34-30°	30-26°	26-22°	22-18°	18-14°	14-10°
I	16	5	0	6	3	5	0	2	6	2	5	7	3	3	7
II	13	1	9	14	7	11	4	2	2	2	3	2	3	6	7
III	6	3	1	2	7	9	1	3	7	8	5	6	6	4	2
I	6	18	3	3	12	9	4	4	7	8	4	5	4	5	5
II	4	1	2	16	11	15	3	0	5	9	7	6	6	8	5
III	7	9	0	14	10	19	0	2	1	4	2	7	6	8	6



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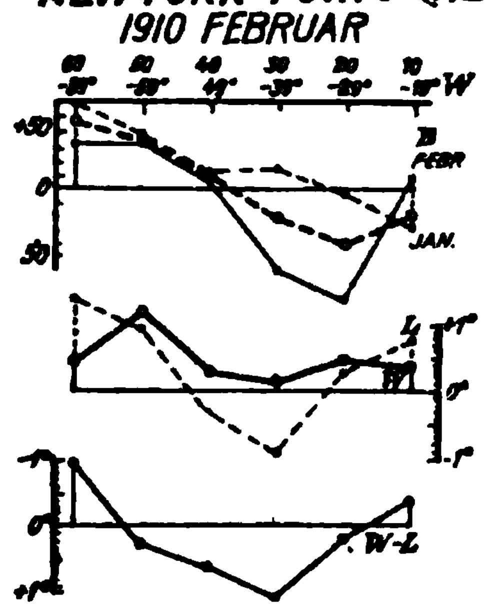

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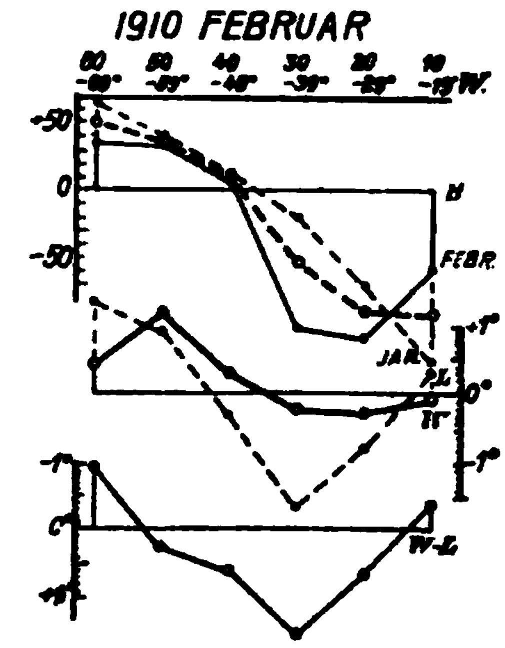

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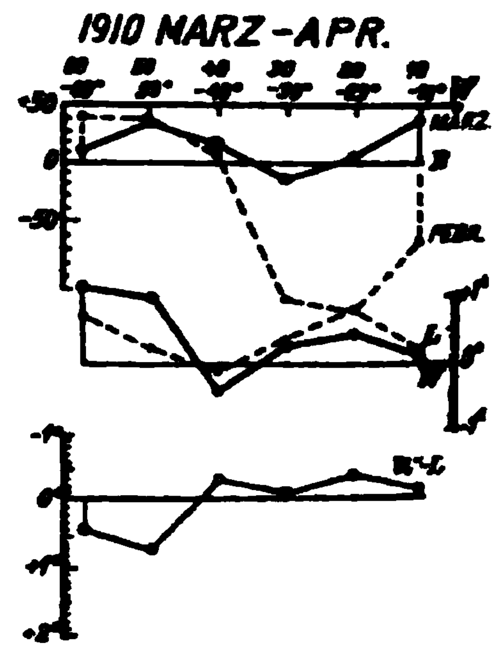
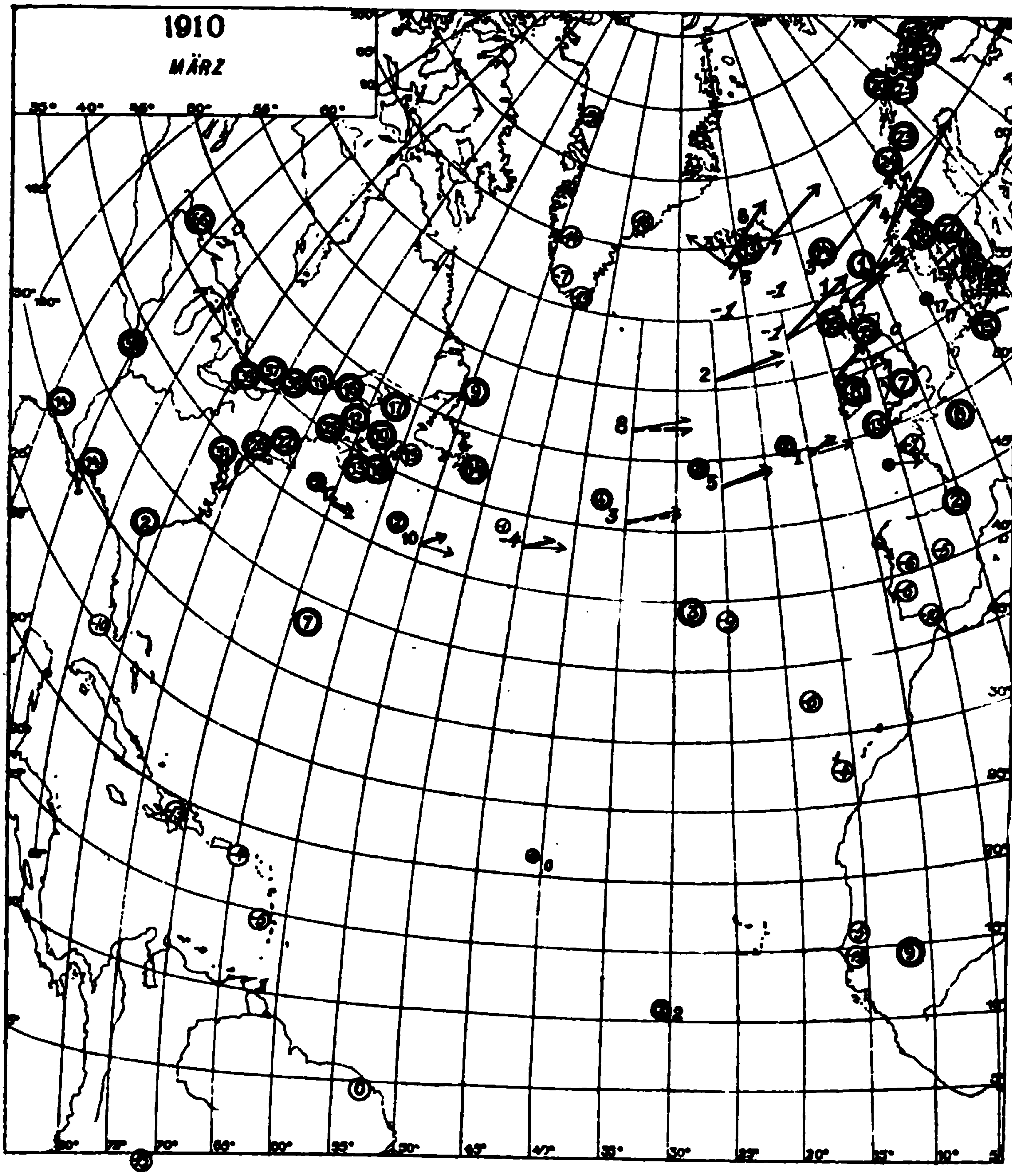
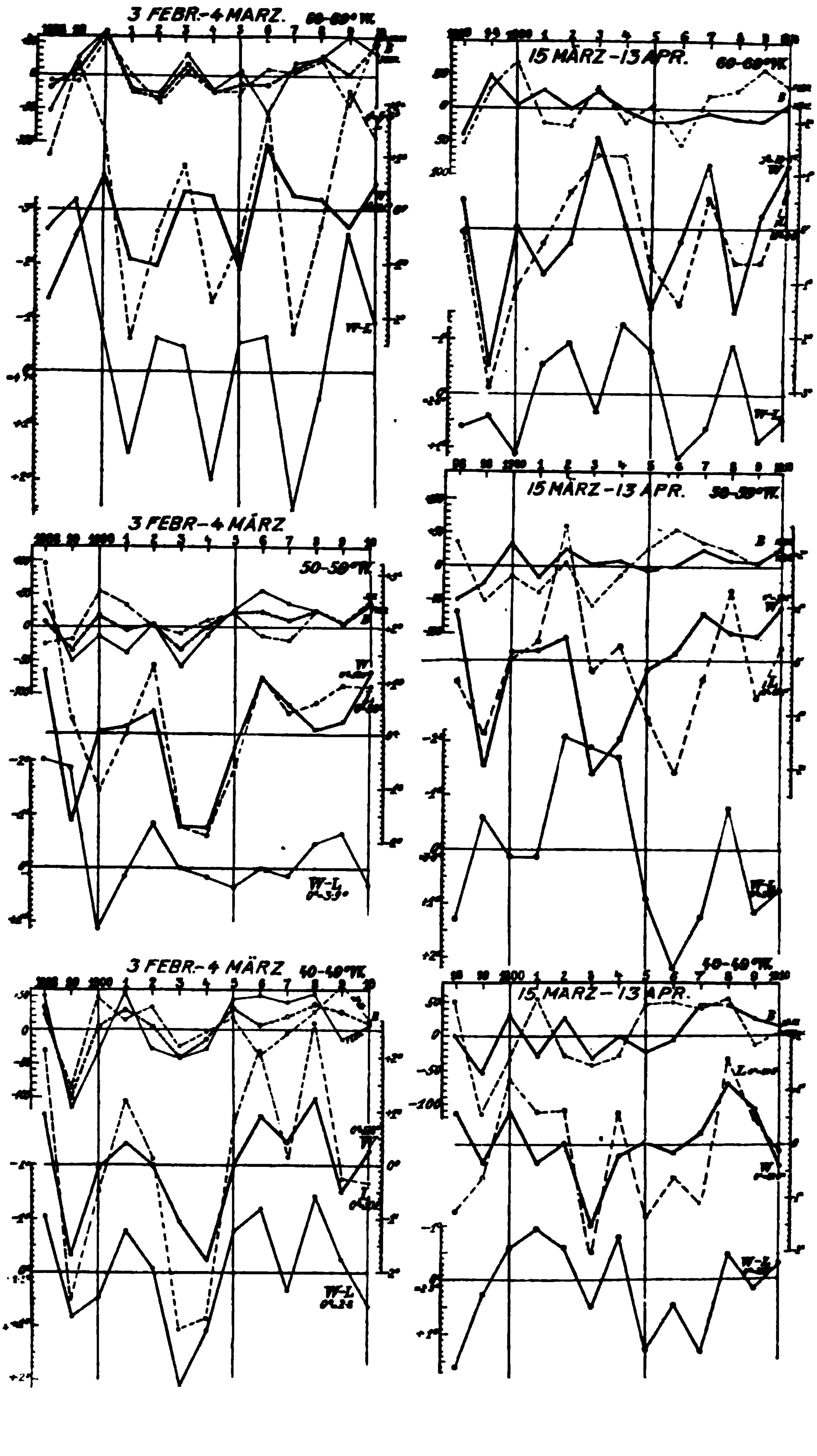




1910

DEKADE	70–66°	66–62°	62–58°	58–54°	54–50°	50–46°	46–42°	42–38°	38–34°	34–30°	30–26°	26–22°	22–18°	18–14°	14–10°
I	1	24	9	4	31	5	6	7	7	5	5	7	5	4	3
II	7	3	12	11	17	7	4	1	2	5	6	0	2	1	4
III	3	2	14	8	22	10	1	4	6	4	5	5	5	3	0
I	1	15	4	3	23	1	4	7	5	9	6	5	5	4	2
II	1	8	7	4	20	6	3	1	1	1	3	3	1	2	1
III	10	32	14	6	21	11	1	5	0	3	6	4	0	2	3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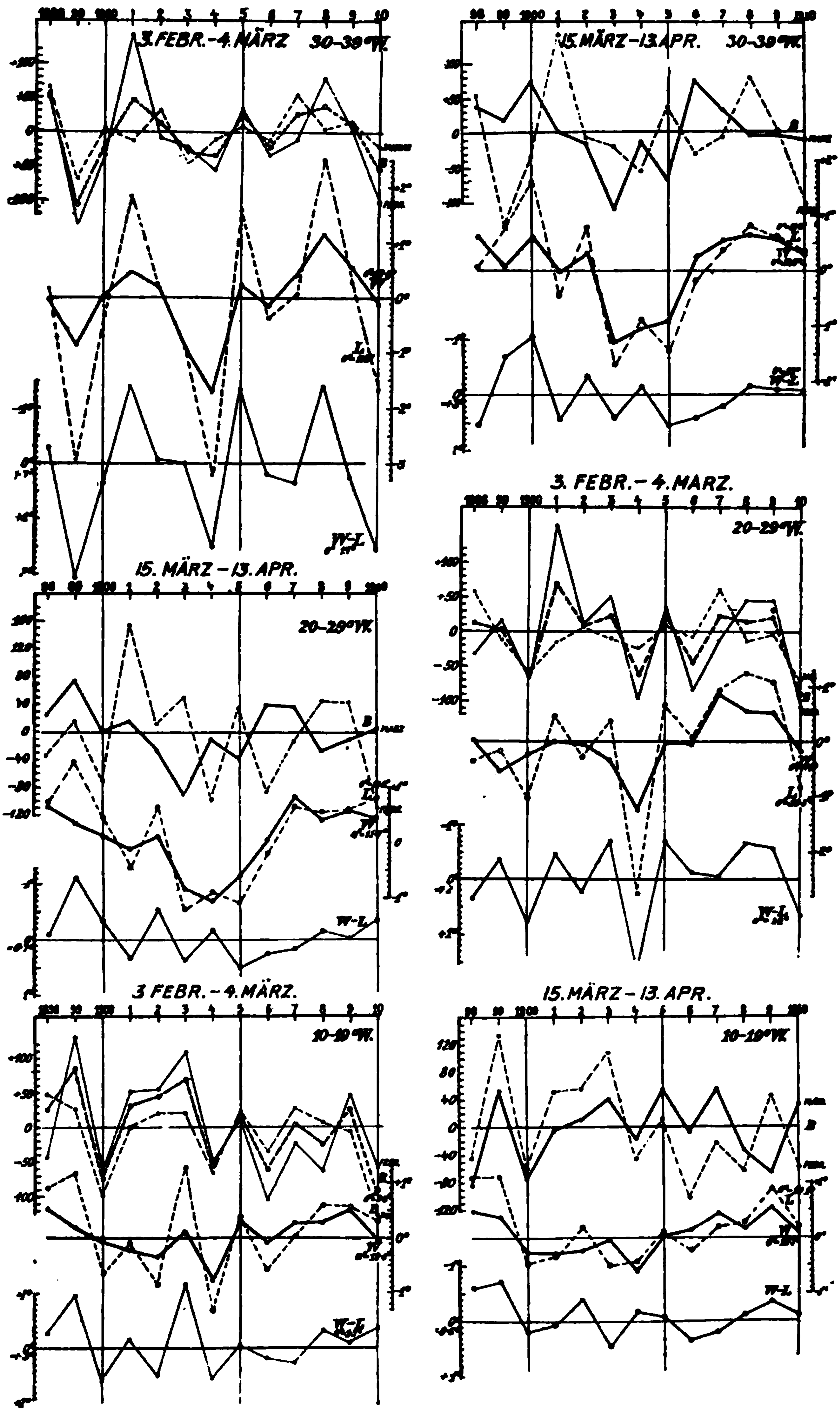
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20-29° W.
3. FEBR.-4. MÄRZ.
20-29° W.
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10-19° W.
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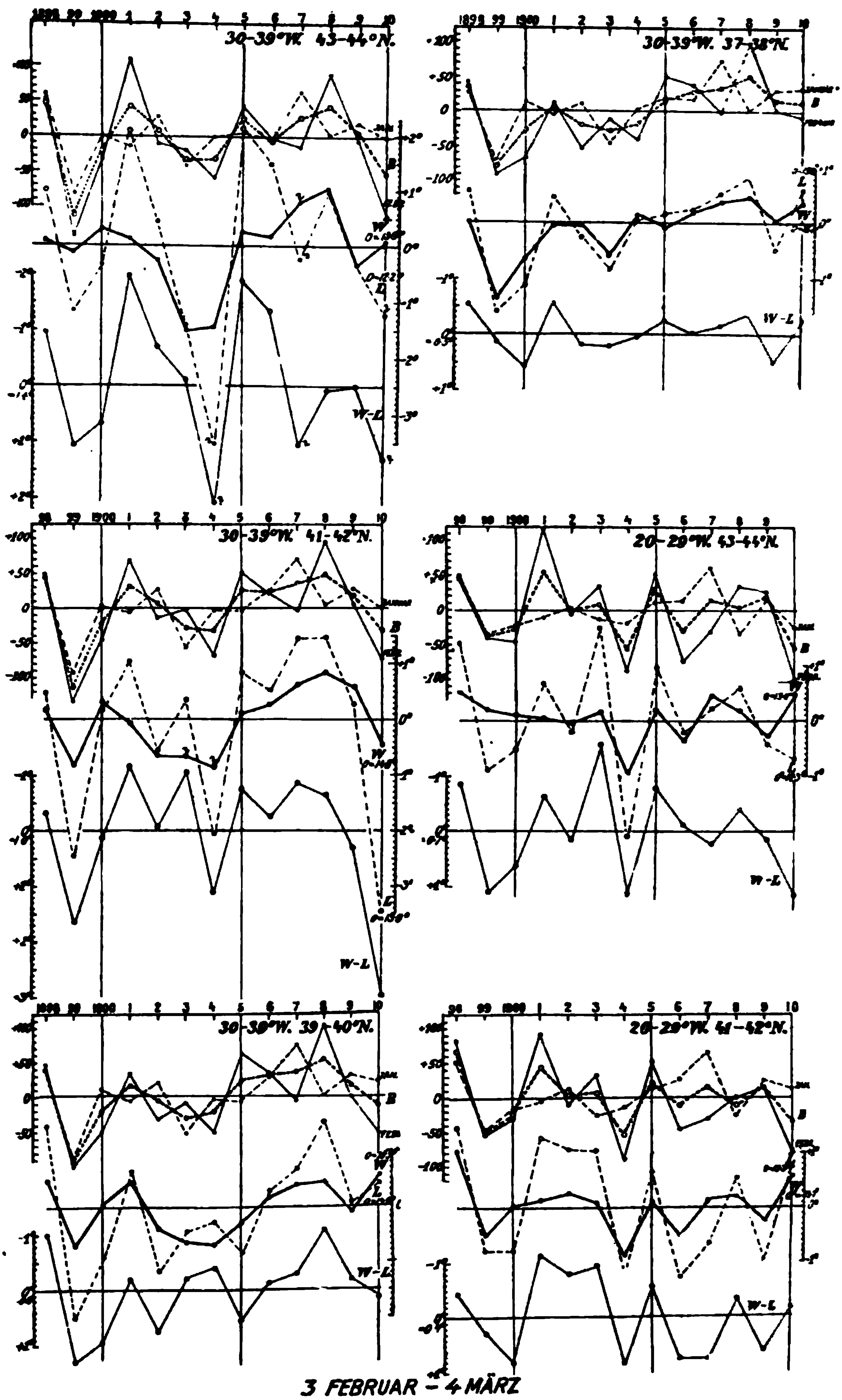

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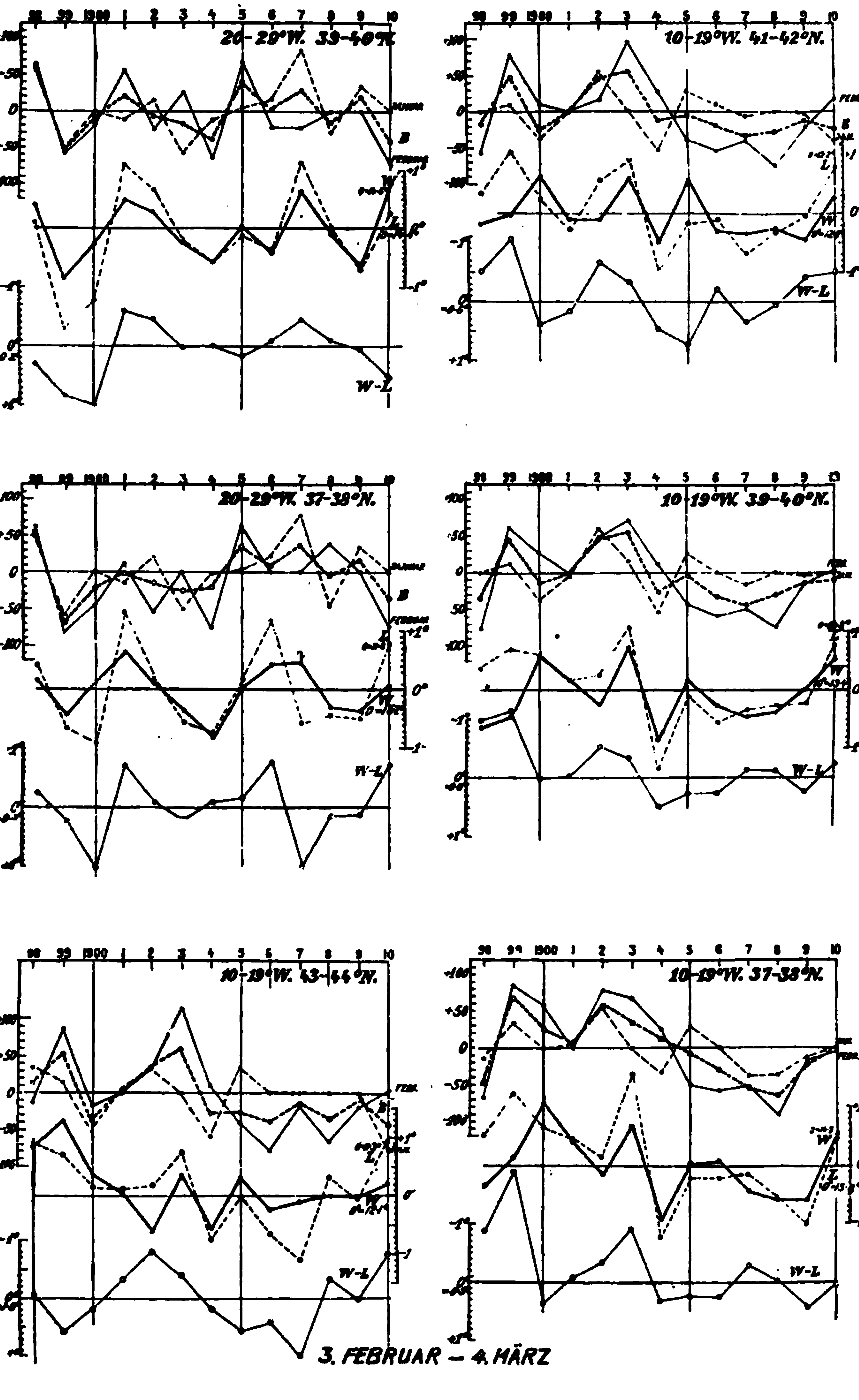

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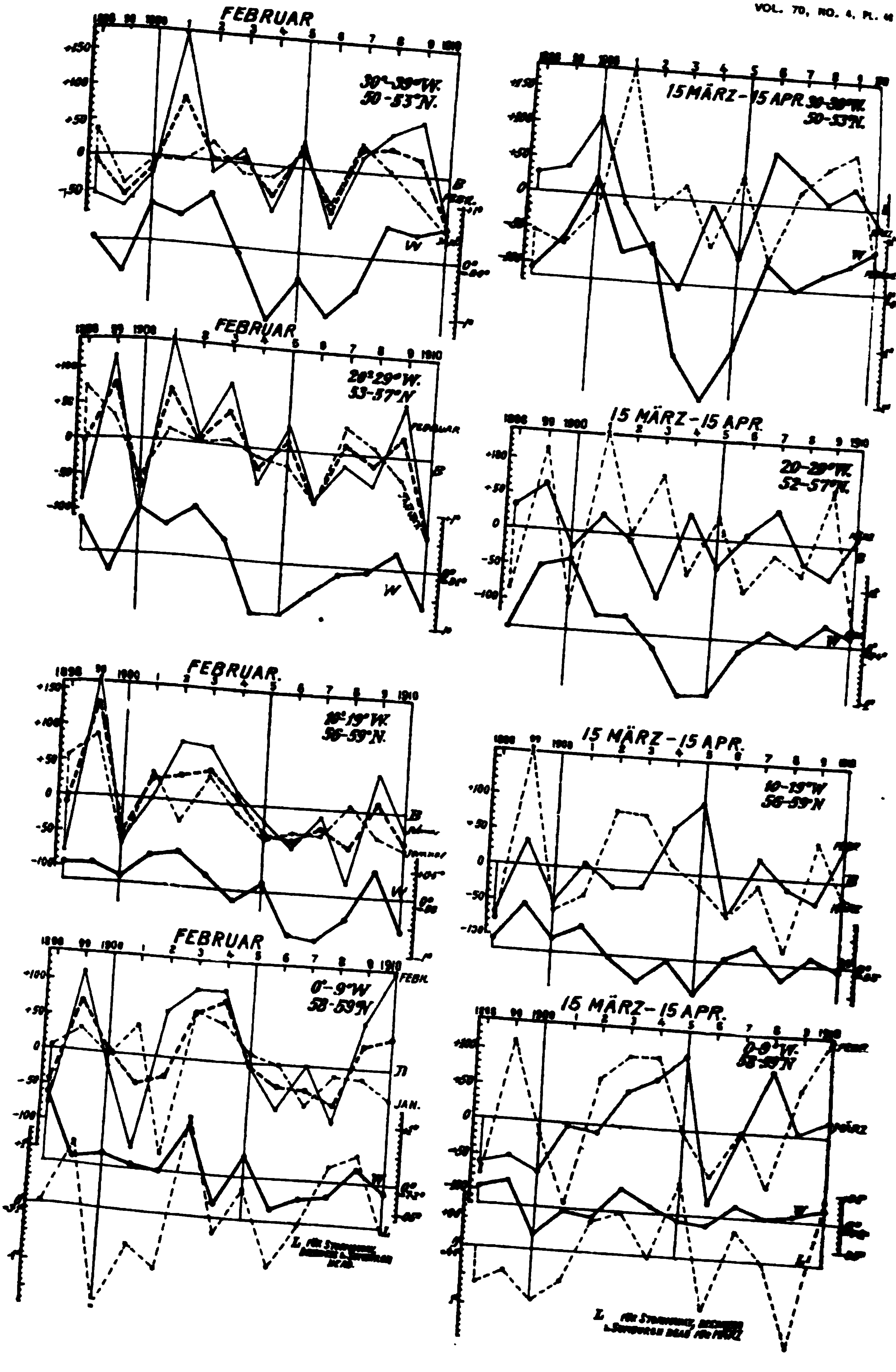
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50-53° N.
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50-53° N.
FEBRUAR
20°-29° W.
53-57° N.
15 MÄRZ-15 APR.
20-29° W.
52-57° N.
FEBRUAR.
10°-19° W.
56-59° N.
15 MÄRZ-15 APR.
10-19° W
56-59° N
FEBRUAR
0°-9° W
58-59° N
15 MÄRZ-15 APR.
0-9° W.
58-59° N

Fig 1.

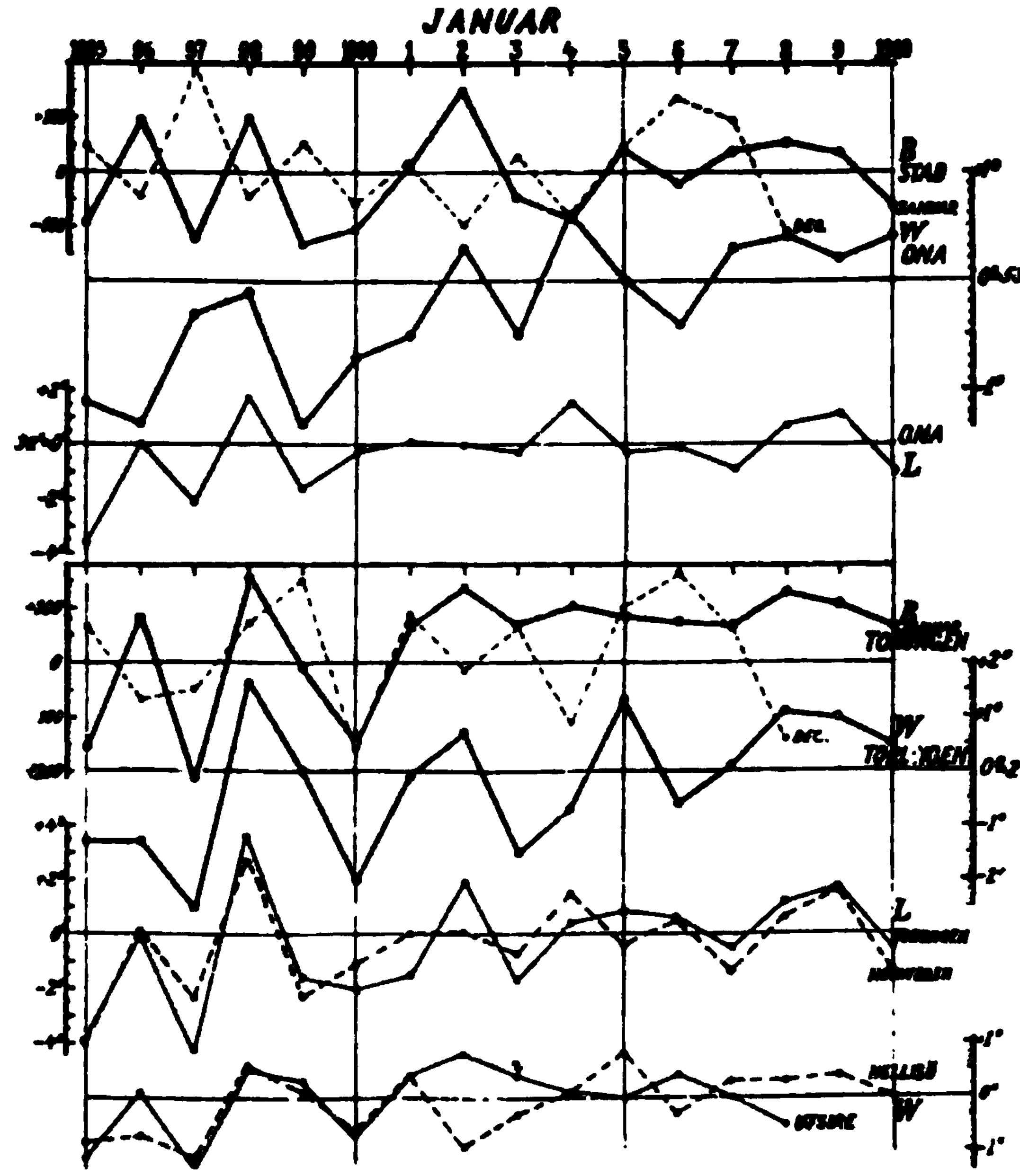
JANUAR
STAD
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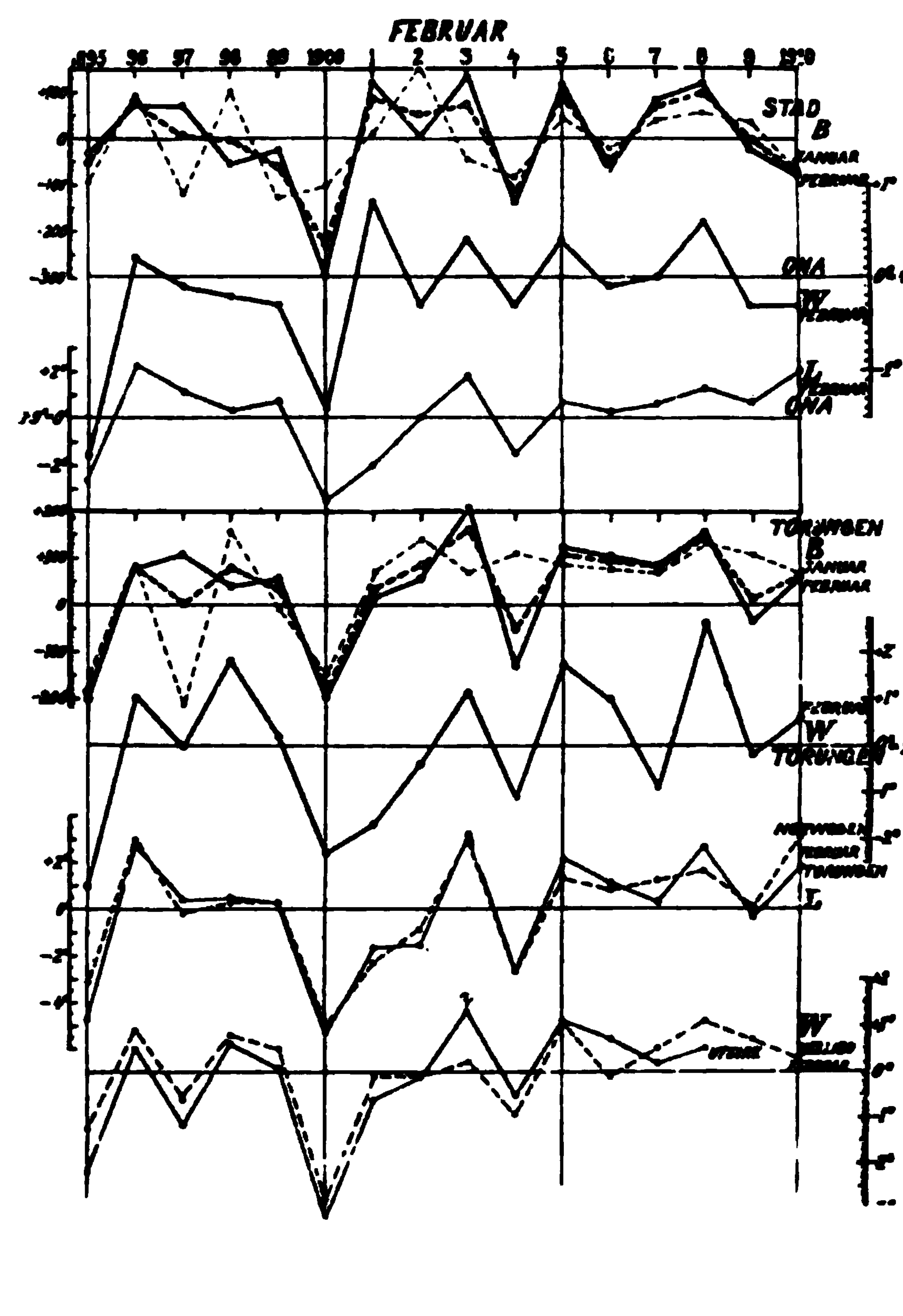
Fig 2.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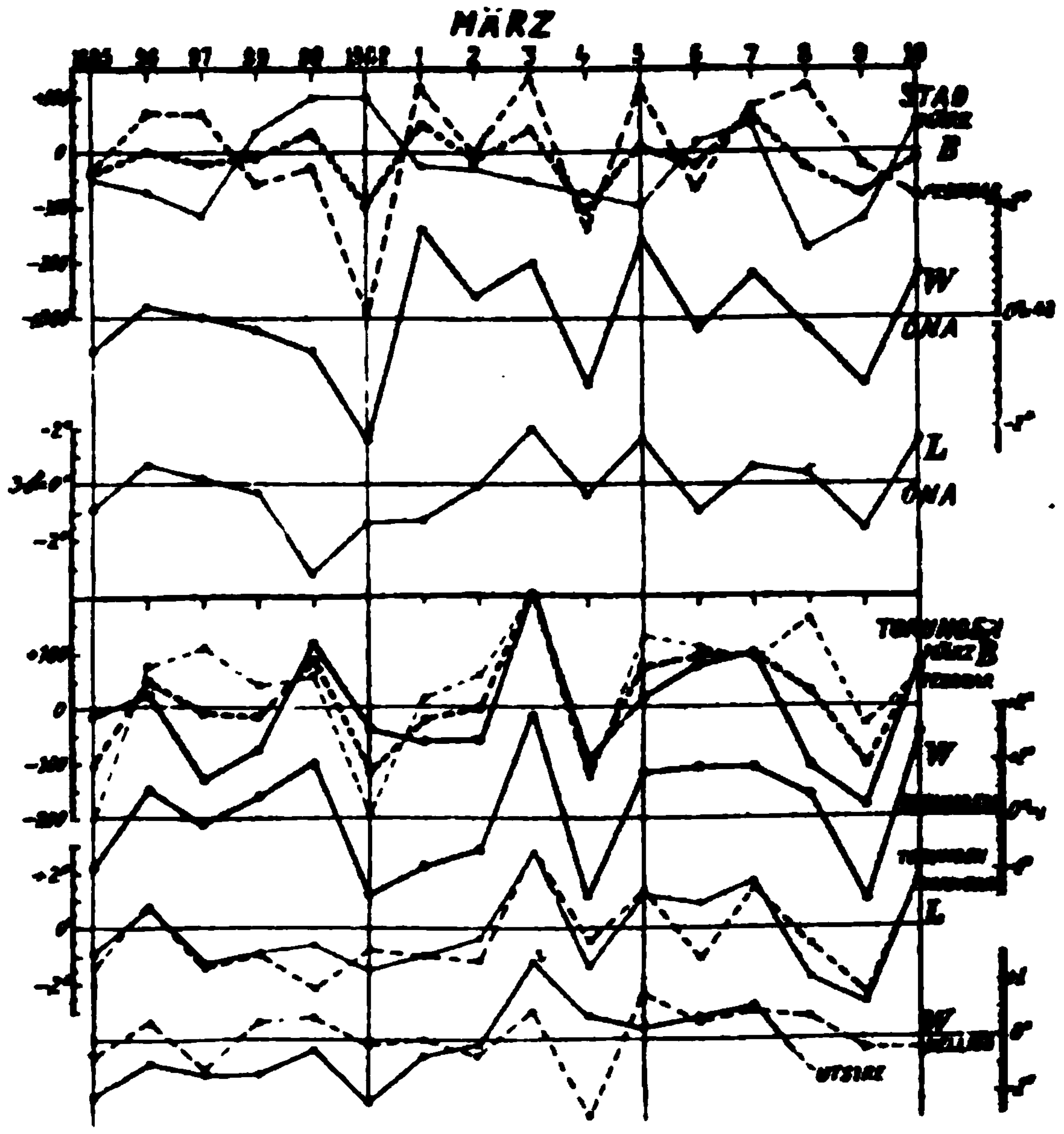
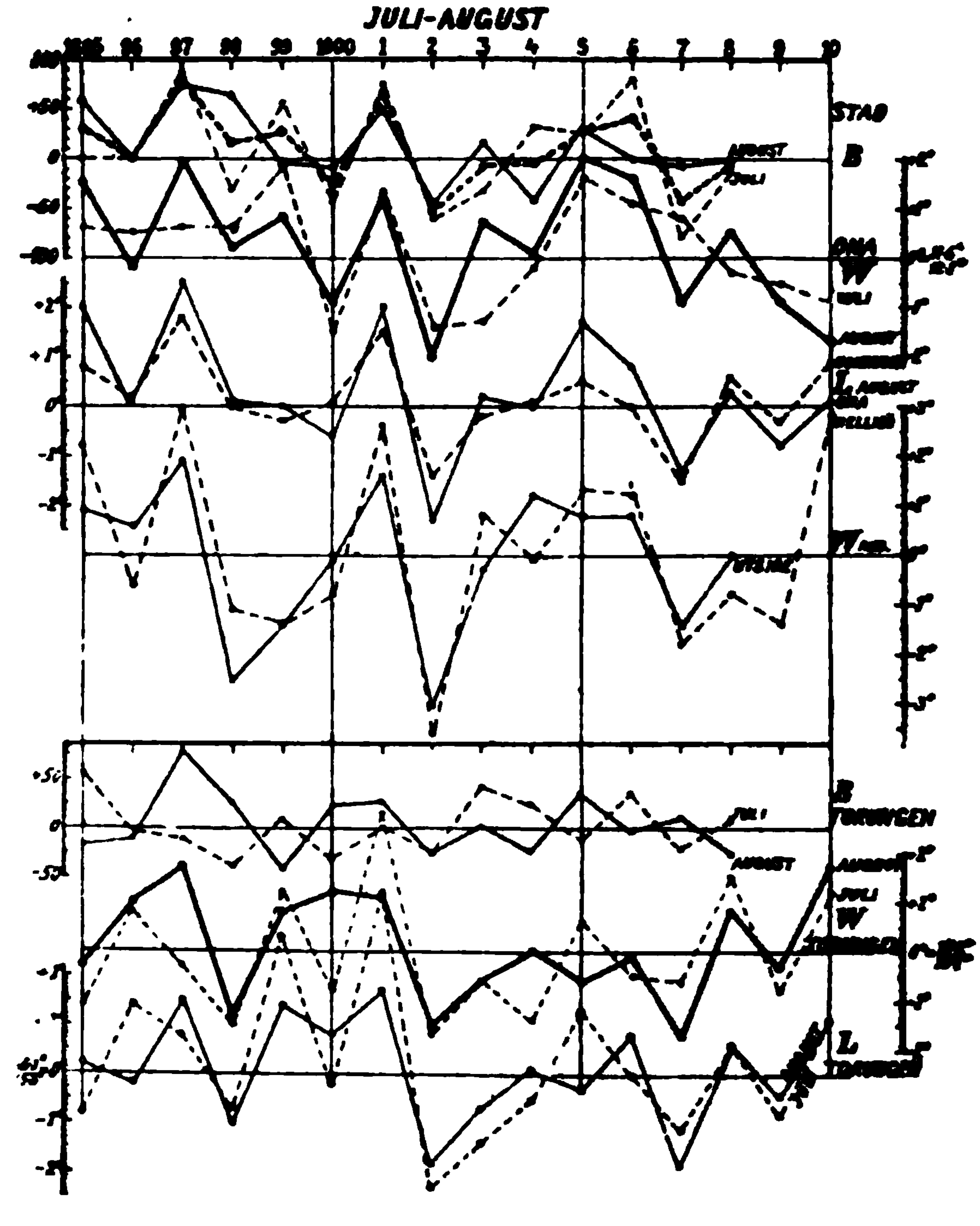

MÄRZ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